ACCESSION NUMBER

1725

APOLLO - DDCSC

copy #12

[redacted]

Z65·10549

NASw-410-30-13-2

N79-76271

(NASA-CR-117570) APOLLO INTEGRATED CHECKOUT PROGRAM. VOLUME 2 - INTEGRATED CHECKOUT EQUIPMENT (General Electric Co.) 158 p

Unclas
00/15 11390

FF No. 602	(PAGES)	(CODE)
	NASA-CR-117570 (NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

[redacted]

GE-410-30-13-2(2) VOL 2

[redacted]

APOLLO

INTEGRATED CHECKOUT IMPLEMENTATION PLAN

VOLUME II

INTEGRATED CHECKOUT EQUIPMENT (U)

Contract NASw - 410

25 JULY 1962

DSD DEFENSE SYSTEMS DEPARTMENT • SYRACUSE, N.Y.

GENERAL ELECTRIC

[redacted]

[redacted]

NASw-410-30-13-2

APOLLO INTEGRATED CHECKOUT PROGRAM

VOLUME II

INTEGRATED CHECKOUT EQUIPMENT (U)

Contract No. NASw-410

~~This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

CLASSIFICATION CHANGE

To UNCLASSIFIED

By authority of [illegible] Date [illegible]

Changed by [illegible]

Classified Document Master Control Station, NASA

Scientific and Technical Information Facility

25 July 1962

~~Group 4~~
~~Downgraded at 3 Year Intervals~~
~~Declassified after 12 Years~~
~~DOD DIR 5200.10~~

Prepared by

General Electric Company
Defense Systems Department
Syracuse, New York

[redacted]

ABSTRACT

The Checkout System concepts are derived from a consideration of the basic operations under the jurisdiction of the Launch Operations Center and the time available to accomplish them. The Checkout System model is based upon a classification of checkout functions into common and unique categories that tend to minimize the impact of space vehicle changes on the Checkout System while providing versatility of control and allowing a step-by-step implementation of the Checkout System.

The purpose of the Integrated Checkout System is to provide qualified personnel with the space vehicle status information required to make launch decisions. The Integrated Checkout System is composed of the Vehicle Checkout System, the Launch Control Center, the Data Evaluation Center, and the communications and interfaces which exist between these complexes.

The Vehicle Checkout System consists of the equipment necessary to verify the proper operation of the space vehicle during the assembly, prelaunch, and launch phases of the program. It includes the following two subsystems.

- The stationary assembly checkout subsystem, essentially oriented toward "maintenance and calibration" type testing, is required during the assembly of the space vehicle, but not at the launch pad for prelaunch tests, and therefore remains in the Vertical Assembly Building when the space vehicle is moved to the launch pad.
- The mobile checkout subsystem, essentially oriented toward "operational" type testing, is used to complement the stationary assembly checkout subsystem during the space vehicle assembly procedures, and is physically mounted on the transporter-launcher and carried to the launch pad with the space vehicle, where it is used in the final tests and preparations for launch.

The Launch Control Center exercises over-all control of the checkout and monitor operations from the time of completed assembly in the Vertical Assembly Building until the spacecraft is injected into its orbit. The Launch Control Center is functionally and physically divided into two major areas: (1) an operational area which will provide real-time control of post-assembly launch operations, and (2) a launch operations central control area which will facilitate the over-all management of launch operations activities.

The Data Evaluation Center provides the facilities necessary to analyze test data in support of launch decisions and to generate new test programs as required to support this function.

A time-phased implementation plan is described. The plan provides an engineering model checkout equipment at Launch Complex 34 at AMR in order to support the command and service modules of the C-1 program. The Integrated Checkout System development, fabrication, and installation are delineated, showing how the R&D and operational phases of the C-5 flight program are supported by delivery, checkout, and operation of the Integrated Checkout System. The Integrated Checkout System is progressively augmented in capability on a schedule compatible with the increasing complexity and scope of the flight programs. A part of both phases of this plan is the utilization of a Checkout System by the contractor as a test bed to prove operation and to develop test programs for flight operation support.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT.)

LIST OF ILLUSTRATIONS (CONT.)

LIST OF TABLES

SECTION 1
INTEGRATED CHECKOUT PHILOSOPHY

1.1 NASA GUIDELINES

The establishment of an integrated space-vehicle checkout system and its supporting elements is to be delineated within the scope of the Apollo program. The following listing of NASA guidelines serves as an envelope of requirements within which the checkout system may be defined.

- The successful achievement of the objectives of the Apollo program require:
  - a. An integrated space-vehicle system checkout at the launch site.
  - b. Individual stage-checkout equipment designed to a common set of ground rules wherever practical.
- Integrated space-vehicle systems must allow for mission-to-mission space-vehicle variations.
- Consider present and planned developments of the various NASA centers.
- Consider information and techniques from other NASA space programs. (Mercury, Gemini, Ranger, etc.)
- The integrated space-vehicle checkout system is to be used within the basic planned launch-complex facility.

1.2 BASIC ASSUMPTIONS

In addition to the NASA guidelines, certain assumptions are necessary in order to provide a working foundation from which checkout philosophies and concepts may be realistically determined.

- Apollo program-reliability criteria require that checkout of the space vehicle be considered as an inline function at AMR.
- The launch complex (39) at AMR consists of the following basic facilities:
  - a. Spacecraft checkout facility
  - b. Stage checkout facility
  - c. Vertical Assembly Building
  - d. Launch facilities

e. Space-vehicle transporter-launchers

f. Launch Control Center

- The launch complex listed above is to serve as the major launch facility for C-5-class vehicles throughout the 1965 to 1975 era.

1.3 STATEMENT OF PHILOSOPHY

The primary objective of this program is to supply a proven and reliable space-vehicle integrated checkout system guaranteed to exercise and check out all Apollo flight systems consistent with the program schedules and missions. The space-vehicle integrated checkout system is defined as the combination of checkout equipments, procedures, information, and personnel that are required to enable the Launch Operations Center to successfully control and execute the space-vehicle assembly, checkout, and launch operations. The checkout system will function within planned facilities, ground support equipment, and operational requirements of the launch complex.

The approach taken in establishing a checkout philosophy requires that one take a hard look at the basic parameters involved, namely, time and tasks. The checkout concepts will result from a detailed consideration of these two basic parameters.

1.3.1 TIME

Of all the parameters that are of concern to the launch complex activities, time is the only one (with the possible exception of man himself) that cannot be redesigned or modified - just used. The problem is to use it as efficiently as possible with the facilities, equipment, and manpower available to the accomplishment of the tasks involved. The launch complex imposes certain time limitations that are functions of launch rates and facility recycle requirements. This, in turn, creates a time envelope within which the basic tasks, such as space-vehicle assembly, checkout, and launch, must be accomplished. Analysis thus far has shown that the time available for these operations is quite modest for the expected launch rates of the 1965 to 1975 era (see Section 1.5.1).

1.3.2 TASKS

The major inline tasks to be accomplished within the launch complex are assembly, checkout, and launch of the space vehicle. All other functions are essentially in support of these basic tasks. In an over-all sense, they are sequential; however, in actuality, the checkout function is interspersed throughout the space-vehicle assembly and launch operations. Figure 1-1 illustrates a basic cycle of these operations for one space vehicle. The frequency of the various checkout operations shown is primarily a function of past history. It is desirable to minimize this frequent checkout from the standpoint of running time on the space-vehicle systems, as well as the time consumed in the setup and performance of these tests. The achievement of this objective requires a greater depth of knowledge of the performance-versus-time characteristics of the space-vehicle systems and the trade-offs involved, so that each checkout operation can, in turn, enhance the gaining of this knowledge.

The nature of the checkout task within the launch complex is influenced by two major considerations. First, is the space vehicle functioning as it was intended to function, and secondly, if functioning, how long will it continue to function properly? Conversely, if the space vehicle is not functioning properly, what is the cause of the malfunction and the recommended course of action concerning the repair and the resulting effect on the space-vehicle status?

The assembly phase encompasses all activities that are devoted to the assembly of the space vehicle in the Vertical Assembly Building, starting with the erection of the first stage on the transporter/launcher, through to the mounting of the uppermost stage of the spacecraft. The checkout tasks that are unique to this phase of the operation serve to validate the assembly operations and provide means to facilitate the checkout adjustments and calibrations necessary to the stage mating process. The launch phase of the operation commences once the space vehicle is committed to leave the Vertical Assembly Building, and includes all succeeding activities through launch and insertion.

The accomplishment of the assembly, checkout, and launch tasks within a given time envelope requires equipment, procedures, and manpower that are integrated into a smoothly functioning process that is controlled in a manner such that the test objectives are not lost. Supervisory control of the launch complex imposes requirements that must be reflected in the performance of equipment and personnel. The focal point of control for the launch complex is the Launch Control Center.

It is through this portion of the space-vehicle integrated checkout system that the supervisory personnel of the Launch Operations Center have access to all information vital to the control of all phases of the launch complex.

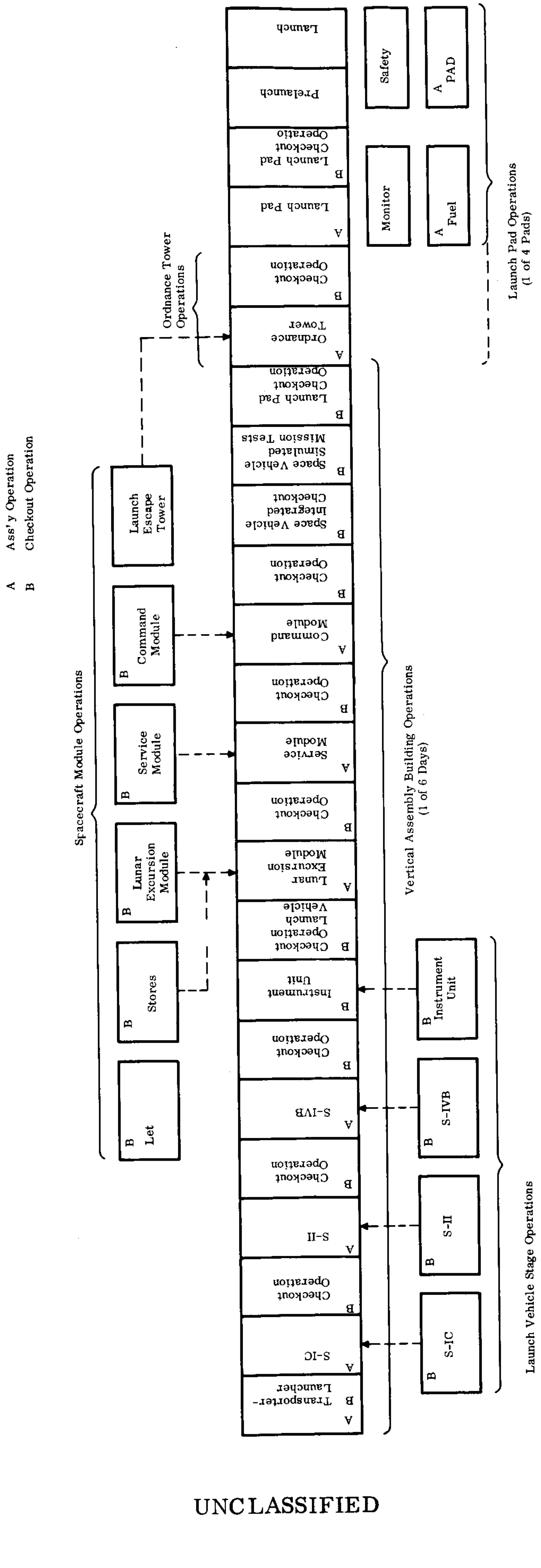


Figure 1-1. Space Vehicle Launch Complex Flow and Operations

1.4 STATEMENT OF CONCEPT

1.4.1 EVOLUTION OF A CHECKOUT CONCEPT

The classical approach to the checkout of an item of equipment has been to provide a piece of test equipment tailored to the specific task at hand. All the required test functions are provided in the checkout device. Such an arrangement is shown in Figure 1-2, where for each item of prime equipment there is a special item of checkout equipment.

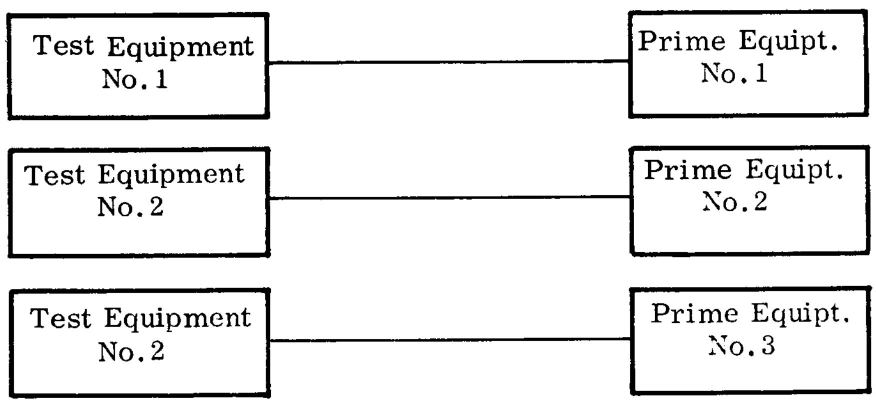


Figure 1-2. Functional Representation of Classical Approach to Test Equipment Design

A change or modification to the prime equipment results in a corresponding change in the test equipment. As the complexity of the item under test increases, it follows that checkout equipment also grows in complexity, and the impact of the change or modification cycle takes its toll on the availability of the test equipment.

If the test functions contained in the equipments illustrated in Figure 1-2 were cateforized, it would be found that they would fall in two general categories, namely, common functions and unique functions. The unique functions are those required by the particular tests performed on the prime equipment, special switching, or due to the special nature of the interface between the two equipments. The common functions would normally contain such items as control, measurement, and readout.

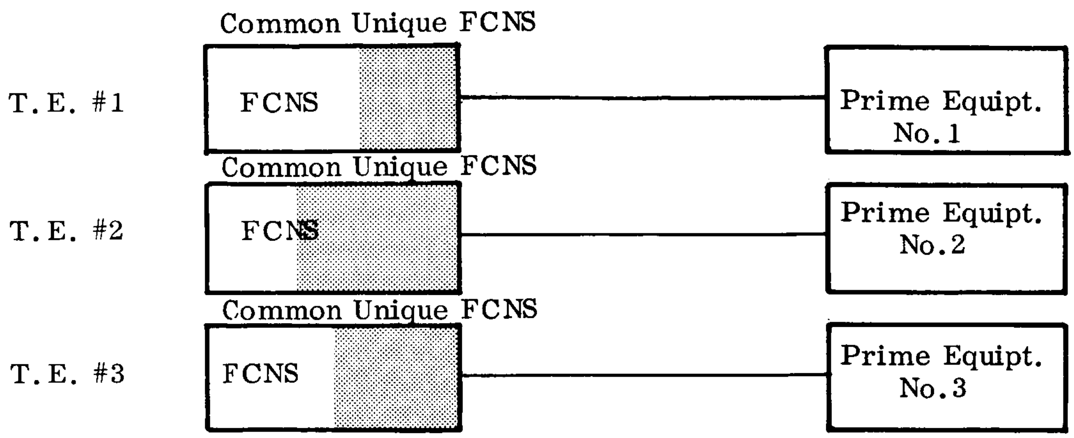


Figure 1-3. Functional Representation of the Division of Test Equipment Functions

Figure 1-3 illustrates, in a quantative sense, how these common and unique functions might exist in the three separate test equipments shown in Figure 1-2. The next step, as shown in Figure 1-4, results from a combination of the common functions into a separate physical unit and using this combination in conjunction with the respective units containing the unique functions. The sharing of a common unit with a number of unique units is shown in Figure 1-5.

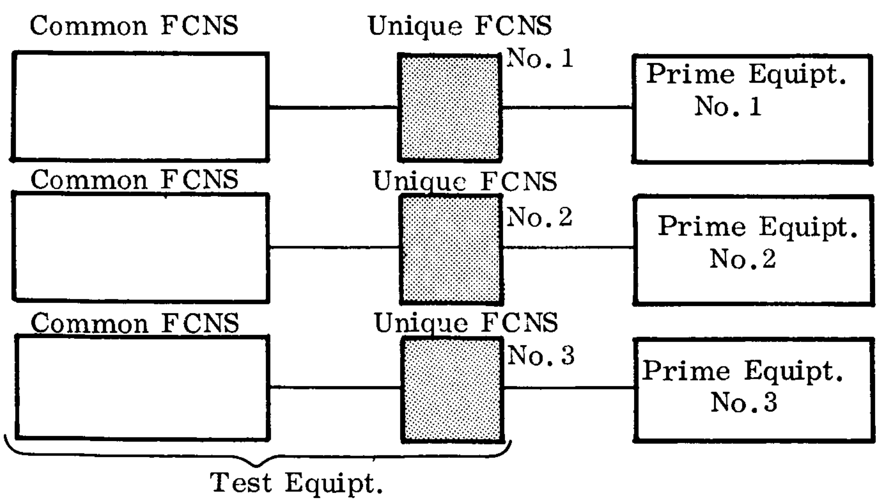


Figure 1-4. Physical Separation of Common and Unique Test Functions

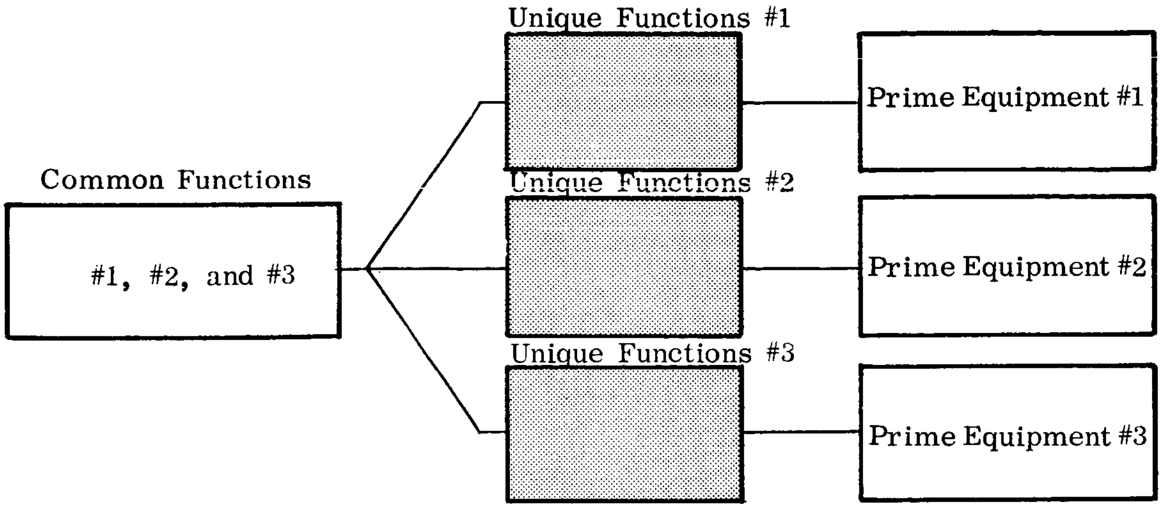


Figure 1-5. Sharing of Common Units with Unique Units

In test situations that involve a dual control requirement because of distance or periodic hazards involved in local control, the common functions as illustrated in Figure 1-5 may be divided into a local control function and a remote or distant control function. (See Figure 1-6.)

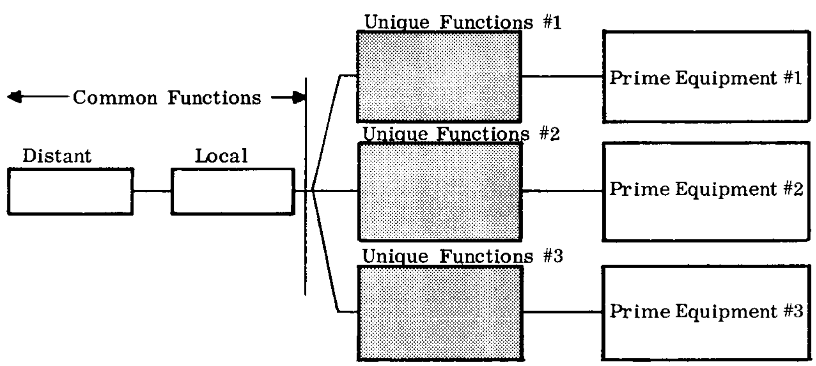


Figure 1-6. Breakdown of Common Units

1.4.2 APPLICATION OF CONCEPT TO SPACE-VEHICLE CHECKOUT

The basic concepts outlined above may be applied to the checkout of a space vehicle where flexibility of operation and control is desirable from both a local and remote control, monitor, and evaluation standpoint. A descriptive model is shown (Figure 1-7) of a checkout complex as it may be applied to the C-5 space-vehicle configuration, where the control functions are subdivided to facilitate the difference in types and levels of the checkout task. A more detailed breakdown of one complete channel of Figure 1-7 is shown in Figure 1-8, where the appropriate functions have been assigned to the respective blocks. Note that the "unique" block, sometimes referred to as an adapter, may contain various stage-peculiar or system-peculiar type functions, whereas the remaining common-functions blocks contain functions that pertain to the degree and types of control and evaluation that are necessitated by the launch complex and its control - not to the space-vehicle interfaces.

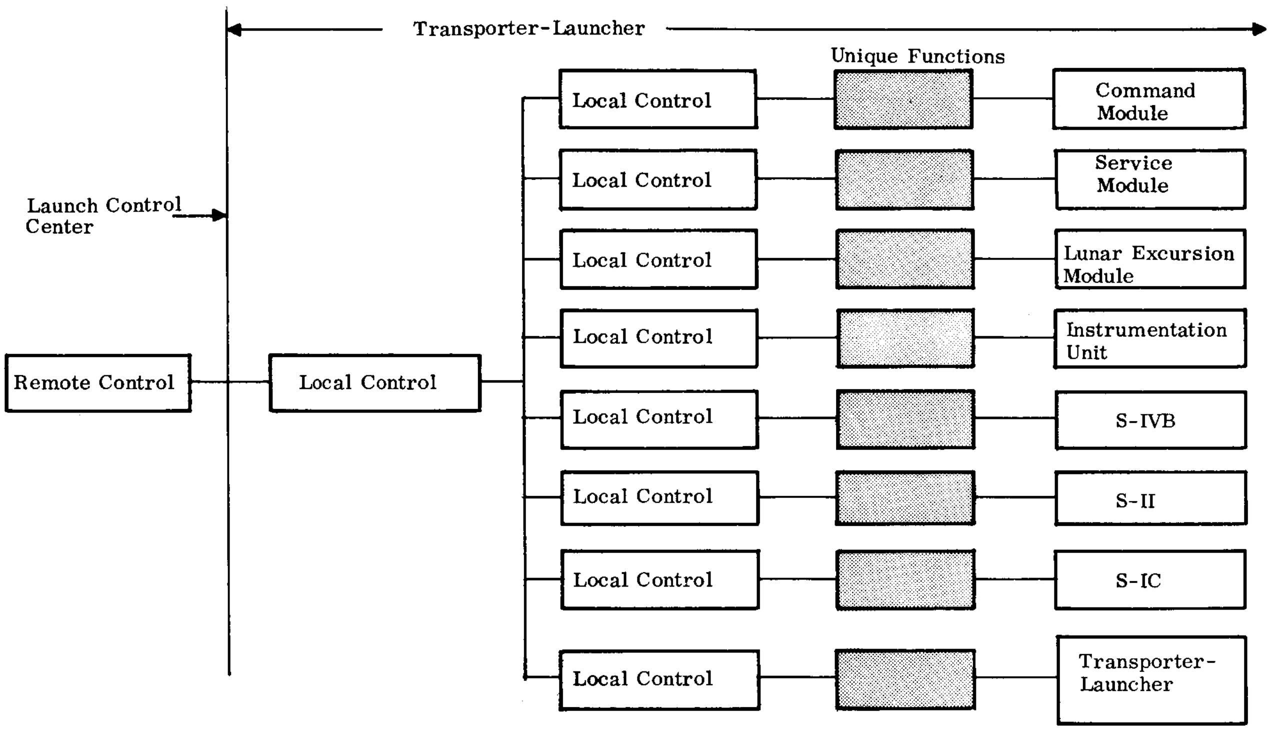


Figure 1-7. Checkout Complex Descriptive Model

The characteristics of the adapter functions must be such that all phases of the checkout tasks may be accomplished from the initiation of the assembly process through the launch of the vehicle. It may be advisable to subdivide some of the adapter functions into assembly test groups and launch test groups to help minimize the equipments that must be transportable. The degree to which this division may be carried out depends a great deal on the extent of repair that is possible once the space vehicle has left the Vertical Assembly Building.

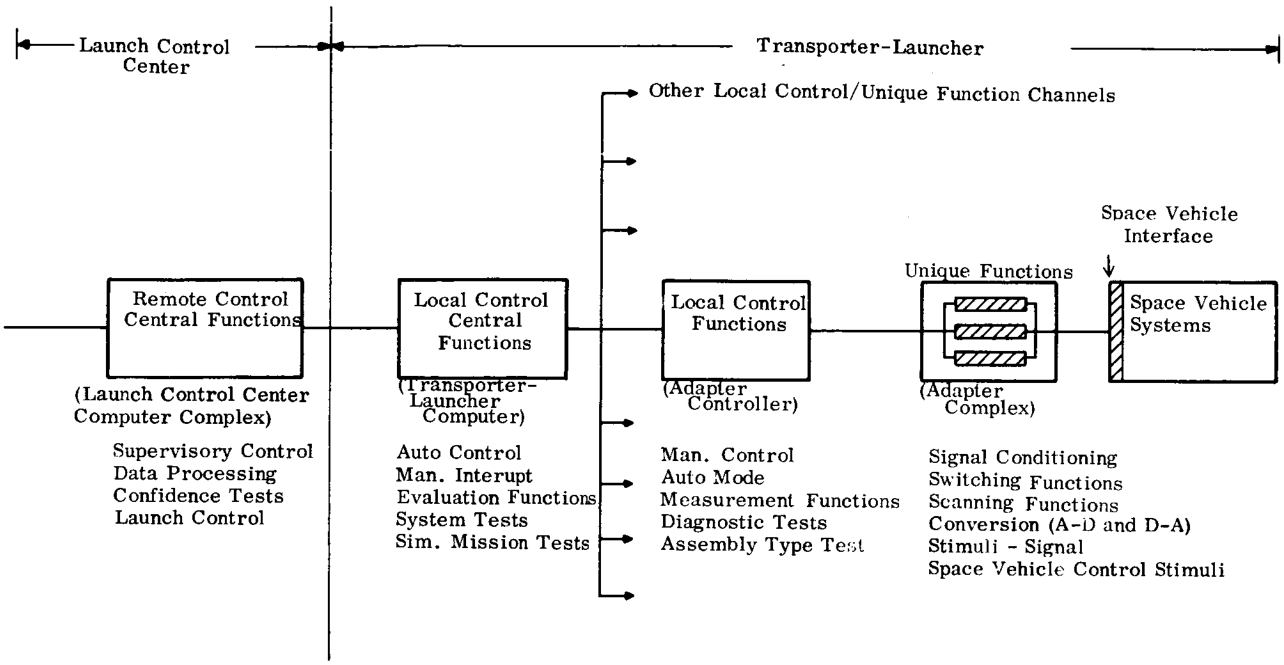


Figure 1-8. Division of Functions for Conceptual Checkout Model

Each space vehicle, because of specific mission considerations, must be considered as an individual item (especially in the research and development phases of the program) and the checkout system must have the flexibility to match these expected vehicle-to-vehicle variations. Changes in vehicle systems and interfaces should, at most, involve modifications of the unique functions in the respective adapter units, but only programming instructions and procedures in the other elements of the checkout system.

The integrated checkout system is contained in, and threads throughout, Launch Complex 39, and the basic conceptual model outlined herein may be implemented to meld the major physical elements of the facility with the space vehicles and the operations personnel. The major facility and checkout elements may be listed as:

a. Launch Control Center - The Launch Control Center will contain those equipments essential to checkout, monitoring, and control operations required to control the assembly, checkout, and launch operations.

b. Vertical Assembly Building - The Vertical Assembly Building facility provides the functions necessary to the assembly and in-process checkout of the space vehicle, and those operations unique to the control of the assembly process.

c. Transporter Launcher - The transporter launcher provides the basic mechanisms required for the transportation, checkout, and launch of the space vehicle.

d. Ground Support Equipment - This category includes all functions unique to the fueling and support of the space vehicle and facilities beyond the scope of the checkout system.

Since the principle function of the integrated checkout program is to provide a measure of vehicle readiness in terms of detailed qualitative data based primarily on current time tests, it is imperative that information flow throughout the integrated checkout system be designed to facilitate the assimulation and analysis of data to assure and verify adequate space-vehicle performance.

1.4.3 MANUAL VERSUS AUTOMATIC CONSIDERATIONS

The nature of the Apollo program and the complexity of the space vehicles involved dictate that the degree of checkout automation be at a low level in the initial phases and gradually increase as experience is gained and the space-vehicle configurations become firm. The checkout system will have to undergo a form of R&D cycle in the same manner as the prime vehicle; however, the checkout-system R&D cycle will have to be compressed. The checkout-system concepts outlined in Sections 1.4.1 and 1.4.2 allow for step-by-step implementation of the basic test functions, as well as a step-by-step evolution of the "automaticity" of the system. It must be kept in mind that there will be some phases of the checkout process that do not warrant automation. For instance, checkout tasks that involve crew participation in the operation and observance of controls and displays will require manual action on behalf of the crew. The checkout system in such instances would serve as a monitor of these manually initiated functions.

Perhaps the most important characteristic of the checkout system will be the fact that its elements must be programmable by either manual or automatic means. The concept provides for adaptive operation to meet the varied test requirements and situations. Since the occurrence of all possible faults and types of failures cannot be predicted completely, the checkout system, in its manual mode of operation, may serve as a real aid during diagnostic fault-locating procedures.

The case for the utilization of automatic techniques, wherever feasible and practical, is strengthened by the fact that automation lends itself to the standardizing of test procedures so that tests may be repeated with a high degree of accuracy. The large number of measurements involved throughout the checkout process (5000 to 8000, for example) and the relatively short period that will be available for monitoring and evaluation of these measurements make it necessary that the bulk of them be accomplished by the checkout equipments with man acting on the results, rather than on the task of collecting and processing data.

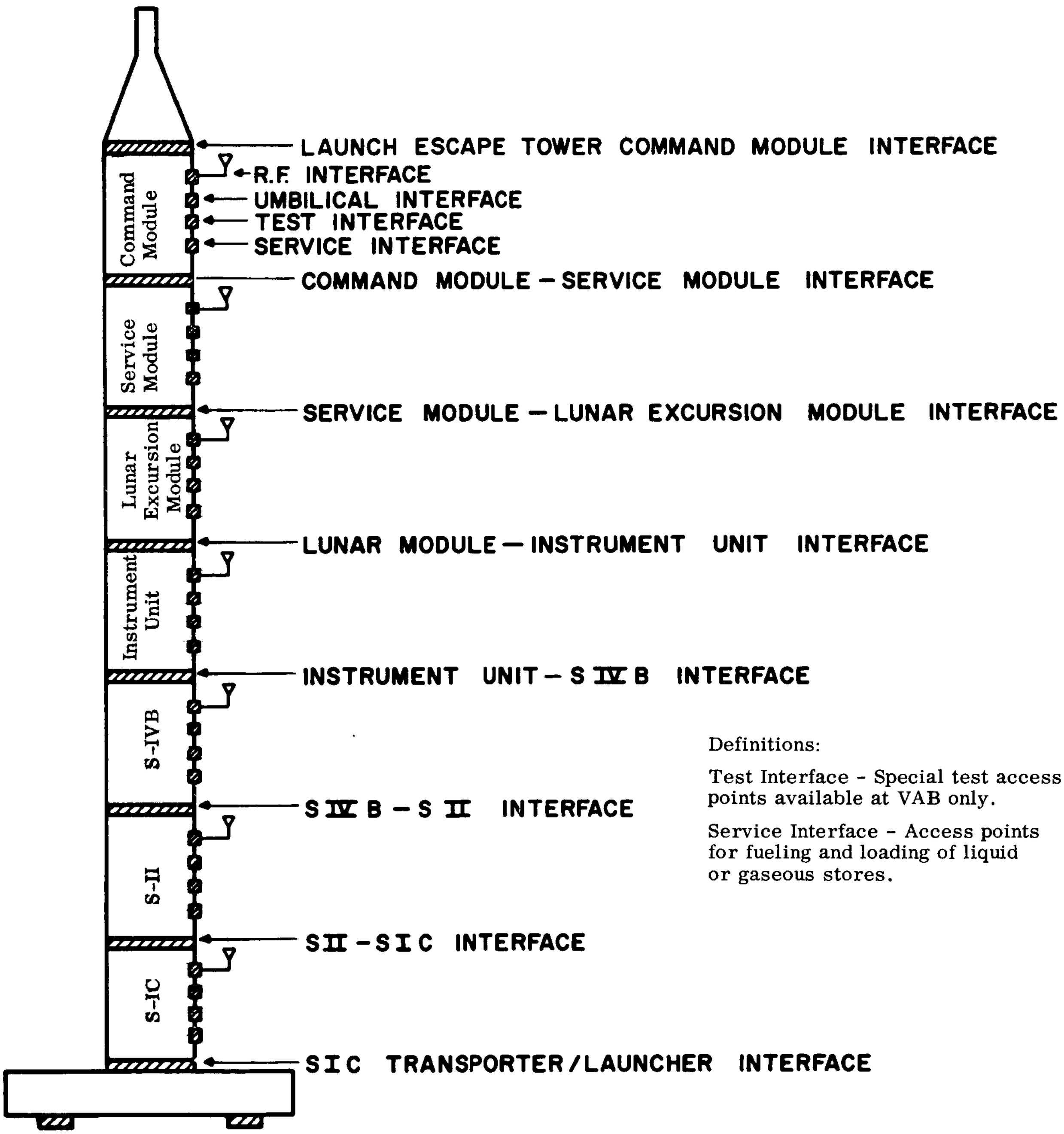
1.4.4 SPACE-VEHICLE SYSTEMS AND INTERFACES

The focal point for the definitions of the integrated checkout system is, of course, the space vehicle itself, supplemented by the operational requirements of the Launch Operations Center. The composite space vehicle, as represented by the C-5 configuration, is illustrated in Table 1-1 by a listing of the major stages and their respective systems. The degree to which any checkout scheme may be implemented is a direct function of the availability and accessibility of the test access and monitor points in the space vehicle proper. The checkout system can "see" only those systems or portions of systems that are made available via the vehicle interfaces. Consequently, the types of space-vehicle interfaces should reflect the important operating characteristics of the vehicle systems, such that a thorough evaluation of performance may be gained. Figure 1-9 represents the types of interfaces that are available to the checkout system at some or all phases of the assembly, checkout, and launch tasks. As an example, the interfaces between the stages may be available only during stage-by-stage buildup at the Vertical Assembly Building. Another situation would be after the space vehicle is assembled in the Vertical Assembly Building - the umbilical, test, and service interfaces are available, whereas the true RF interface is not available for test purposes. After the vehicle has been transported out of the Vertical Assembly Building, then the umbilical and RF interfaces are the ones through which the system may be checked out. This change in space-vehicle/checkout-system interface is as critical to the checkout system as are the types of parameters that are made available through them. Definition of these interfaces are of number-one priority in the establishment of the integrated checkout system.

Table 1-1

Apollo Space-Vehicle Equipment Breakdown
(C-5 Configuration)

SPACECRAFT	LAUNCH VEHICLE
COMMAND AND SERVICE MODULE	INSTRUMENTATION PACKAGE
• Guidance and Control	• Guidance and Control System
Guidance and Navigation	• Telemetry and Instrumentation System
Stabilization and Control	• Electrical Power System
• Service Propulsion System	• Structural System
• Reaction Control System	STAGE S-IVB
• Launch Escape System	• Telemetry and Instrumentation System
• Earth Landing System	• Electrical Power System
• Structural System	• Propulsion System
• Crew Systems	• Structural System
• Environmental Control System	STAGE S-II
• Electrical Power System	• Telemetry and Instrumentation System
• Communication and Instrumentation System	• Electrical Power System
LUNAR EXCURSION MODULE SYSTEM	• Propulsion System
• Lunar Touchdown System	• Structural System
• Guidance Control System	STAGE S-IC
• Reaction Control System	• Telemetry and Instrumentation System
• Propulsion System	• Electrical Power System
• Structural System	• Propulsion System
	• Structural System
	LAUNCH VEHICLE ABORT AND SAFETY SYSTEM



Definitions:

Test Interface - Special test access points available at VAB only.

Service Interface - Access points for fueling and loading of liquid or gaseous stores.

Figure 1-9. Types of Space Vehicle Interfaces

1.5 ANALYSIS OF BASIC CONSIDERATIONS

The times available for assembly, checkout, and launch preparations can be estimated with a high degree of certainty by consideration of launch schedules, number of launch pads, and number of Vertical Assembly Building bays. Preliminary investigation of the available times has been undertaken, assuming the existence of a six-bay Vertical Assembly Building, four launch pads, and considering the following factors.

- Time in the Vertical Assembly Building per vehicle. This period must be shared by assembly and integrated checkout functions, as well as certain individual stage tests.
- Setup time in the Vertical Assembly Building. This time is needed to change jigs, fixtures, etc., necessary to accommodate a new vehicle. Normally, this time does not start until the vehicle previously assigned to a particular Vertical Assembly Building bay is launched. Time to refurnish the transporter/launcher could become an important factor in the Vertical Assembly Building setup time.
- The Vertical Assembly Building to launch pad transit time. This time includes the stop at the ordnance tower and any pad assembly time.
- Pad time. This time represents the time from vehicle reception to launch time.
- Pad refurbish time. This interval allows time for modifications and repairs at the pad from one vehicle launch until the pad is available for another launch.
- The total number of launches, from the complex, in one year.
- The effects of the distribution of these launches on the available time.

Examination of the Vertical Assembly Building operations will allow placing reasonable bounds on the time available for systems assembly and checkout in the Vertical Assembly Building. For example, considering the assembly and checkout procedure presented in Figure 1-10, the times available for stage and integrated checkout in the Vertical Assembly Building have been determined for one-week and two-week pad times. This data is presented in Figure 1-11 and shows only a two-to-one variation in available time for the wide variation of parameters given.

The sum of the weeks available on the pad and in the Vertical Assembly Building as a function of the number of launches per year is shown in Figure 1-12. The available

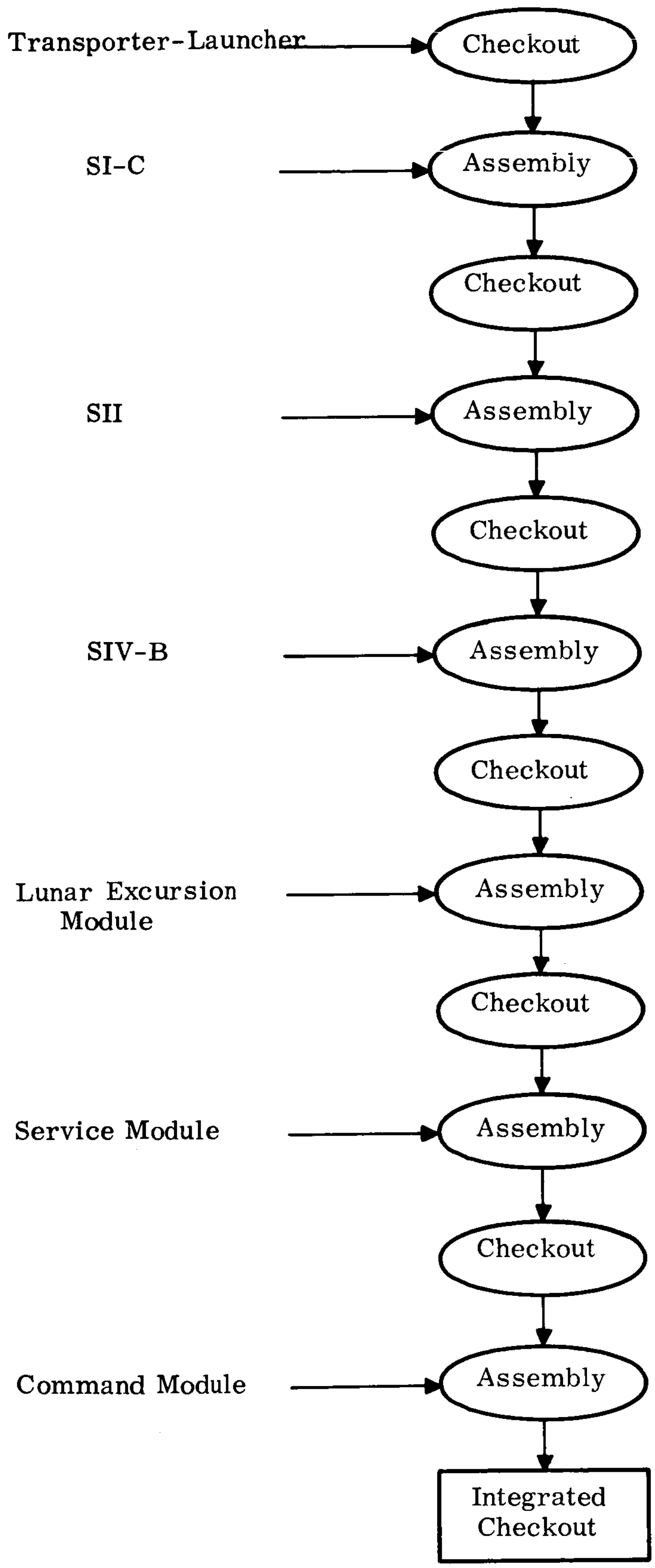


Figure 1-10. Vertical Assembly Building Integrated Checkout Operations Flow

time lies somewhere within the shaded area and is quite insensitive to the assumed conditions. The greatest variation is of the order of 30 percent at the higher launch rates.

The effect of launch distribution upon the total time that a Vertical Assembly Building bay is tied up is presented in Figure 1-13. The effect of launch distribution upon Vertical Assembly Building availability times is seen to be slight for a particular yearly launch rate. For this particular analysis, it was assumed that no more than four vehicles can be launched in any two-week period, and no more than six vehicles can be launched in any seven-week period.

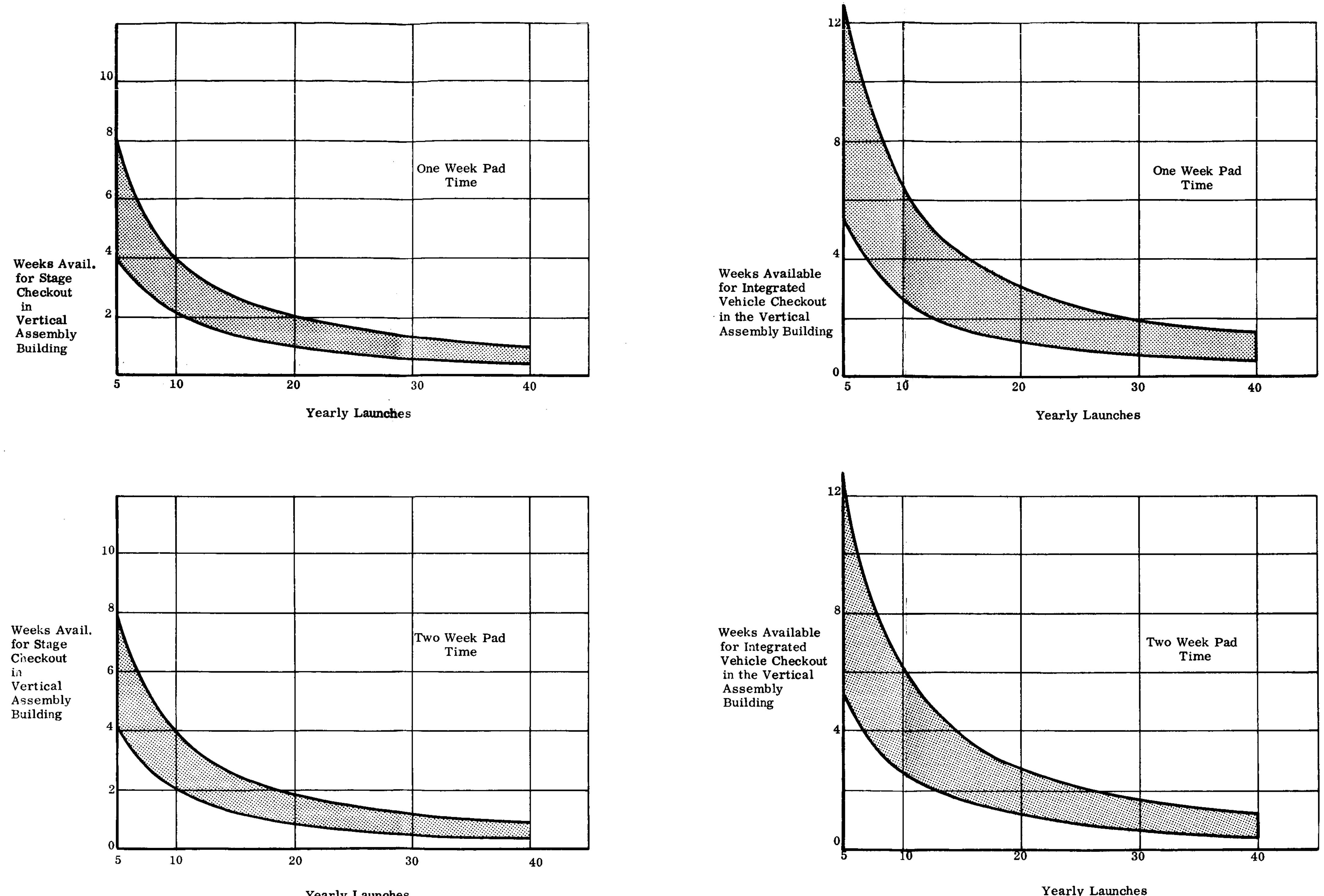
Figure 1-14 illustrates the basic relationships between launch-pad refurbish time, time available for Vertical Assembly Building/launch-pad operation, and yearly launch rate for a six-bay Vertical Assembly Building/four-launch-pad facility combination. The interdependence of these basic parameters define the envelope of operation for the assumed launch facility. Figure 1-15 is an expanded view of these basic relationships in the vicinity corresponding to 26 and 52 launches per year.

Figure 1-16 shows the time allotted for each spacecraft in order to maintain a yearly launch rate. A seven-bay spacecraft facility is assumed.

Several assumptions will now be made concerning launch schedules and learning curves. These assumptions are summarized in Figure 1-17.

The recycle percentage is an equivalent average of many factors: Some delays will only be the order of a day to allow a black-box replacement, others will be of the order of several weeks because of major malfunctions. A figure of 30 percent implies that, on the average, the complete Vertical Assembly Building-through-launch time of three out of ten vehicles will be inefficiently utilized. The result, weeks available in the Vertical Assembly Building as a function of the year, is given in Figure 1-18. Figure 1-19 gives the corresponding times for checkout. Note that with a steady-state yearly launch of 30 vehicles, about one week is available for total systems checkout.

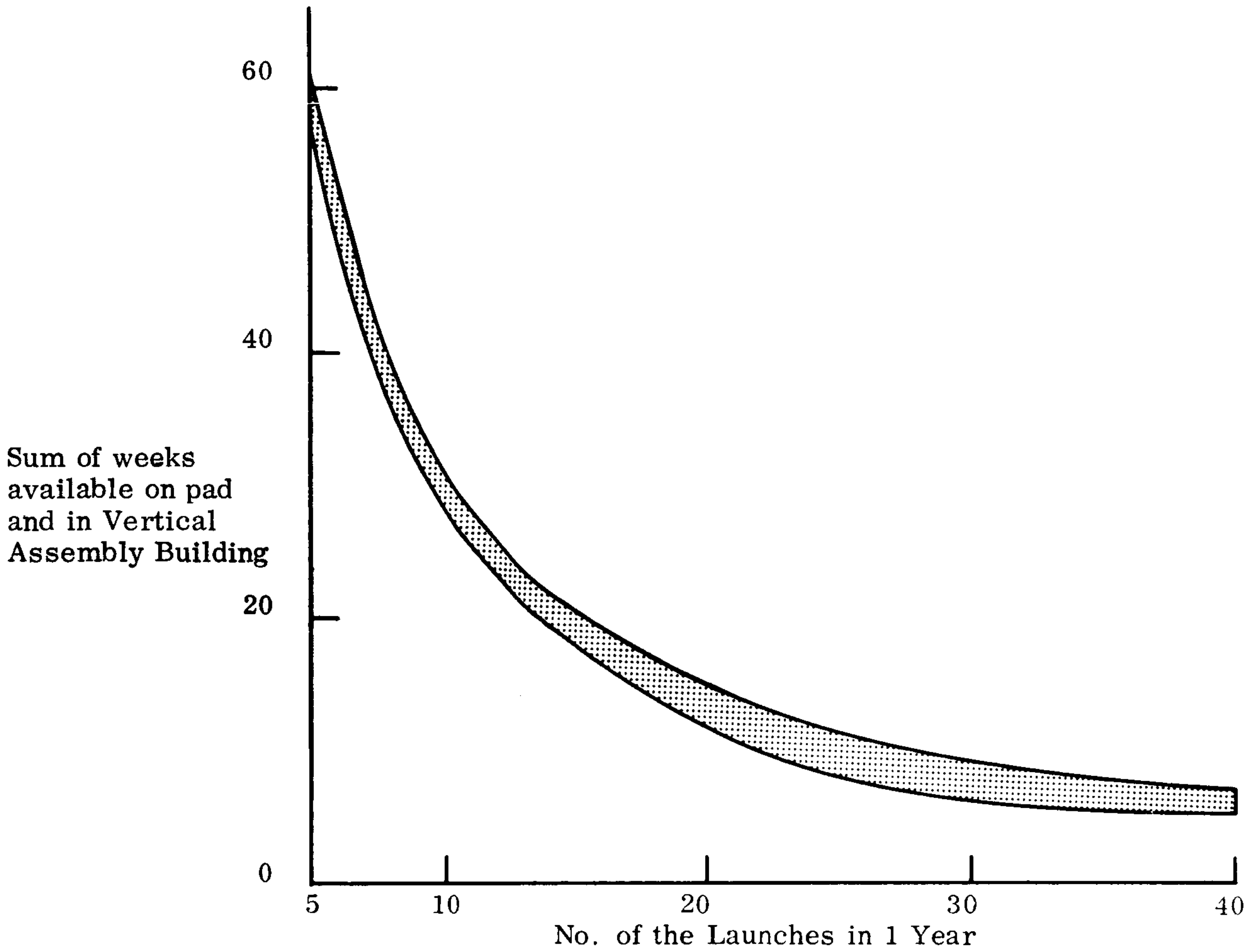
The times available for vehicle checkout on the pad will be less than this. At the same time, however, tests at the pad location should be less detailed and time consuming. In this instance, checkout automation may provide a means to obtain the maximum amount of desired testing in a minimum amount of time.



CONDITIONS:

One Week Pad Refurbish Time
Zero Weeks Vertical Assembly Building
0.1 Week Vertical Assembly Building to Pad Transit Time
Either two or three final integrated vehicle checkouts.
Integrated vehicle checkout time is between 100 and 200 percent of stage checkout time.
Assembly and Checkout Operations in Series

Figure 1-11. Times Available for Stage and Integrated System Checkout in the Vertical Assembly Building for One-Week and Two-Week Pad Times

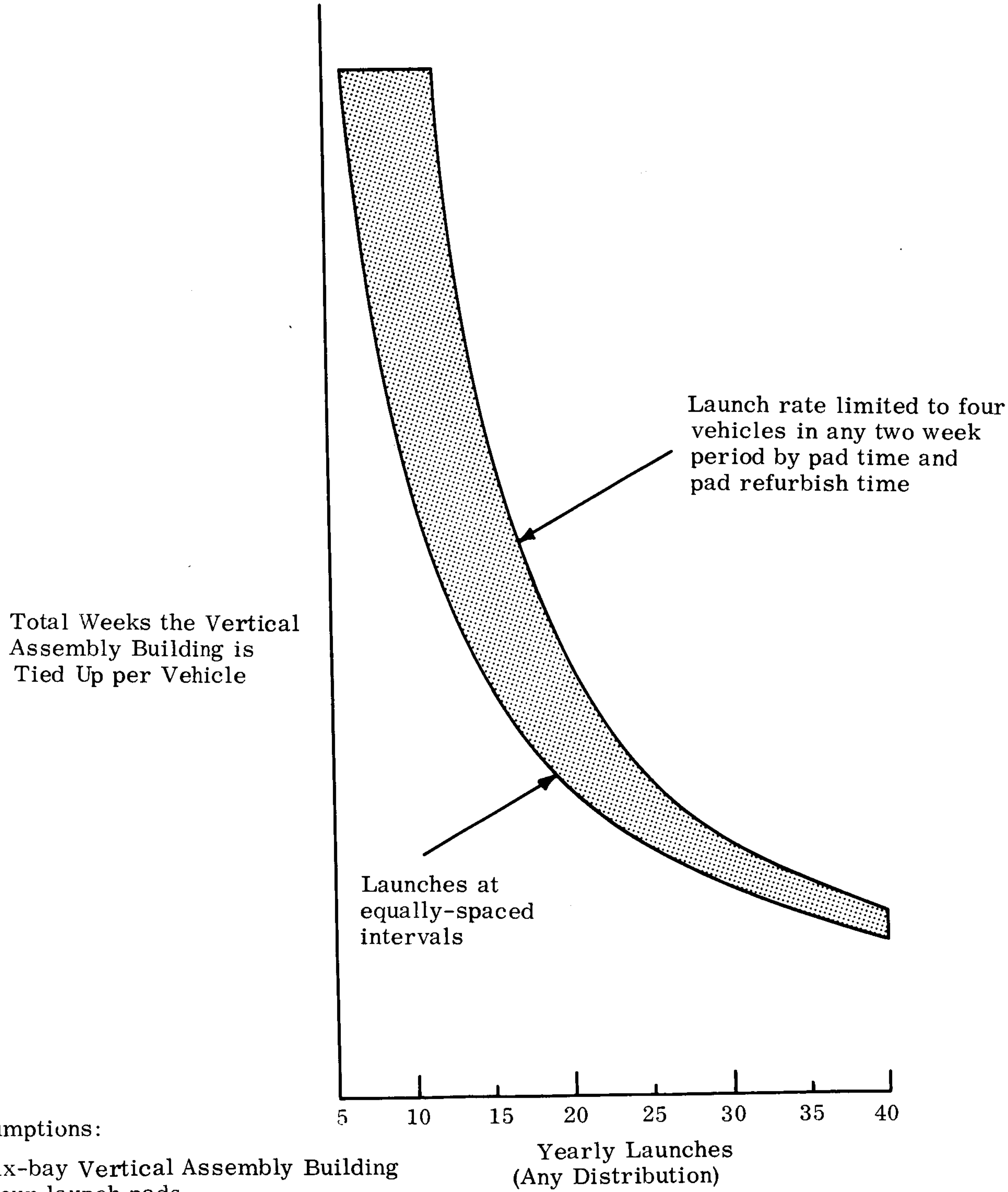


Assumptions:

Six-bay Vertical Assembly Building, Four Launch Pads

Function	Maximum	Minimum
VAB Setup Time	1 week	0 week
Pad Refurbish Time	2 weeks	1 week
VAB to Pad Transit	0.5 week	0.1 week

Figure 1-12. Plot of Sum of Weeks Available in the Vertical Assembly Building and on the Pad as a Function of Yearly Number of Launches



Assumptions:

Six-bay Vertical Assembly Building
Four launch pads
One week pad time
One week pad refurbish time
Six week Vertical Assembly Building time

Figure 1-13. Effect of Launch Distribution Upon Total Time Vertical Assembly Building is Tied Up

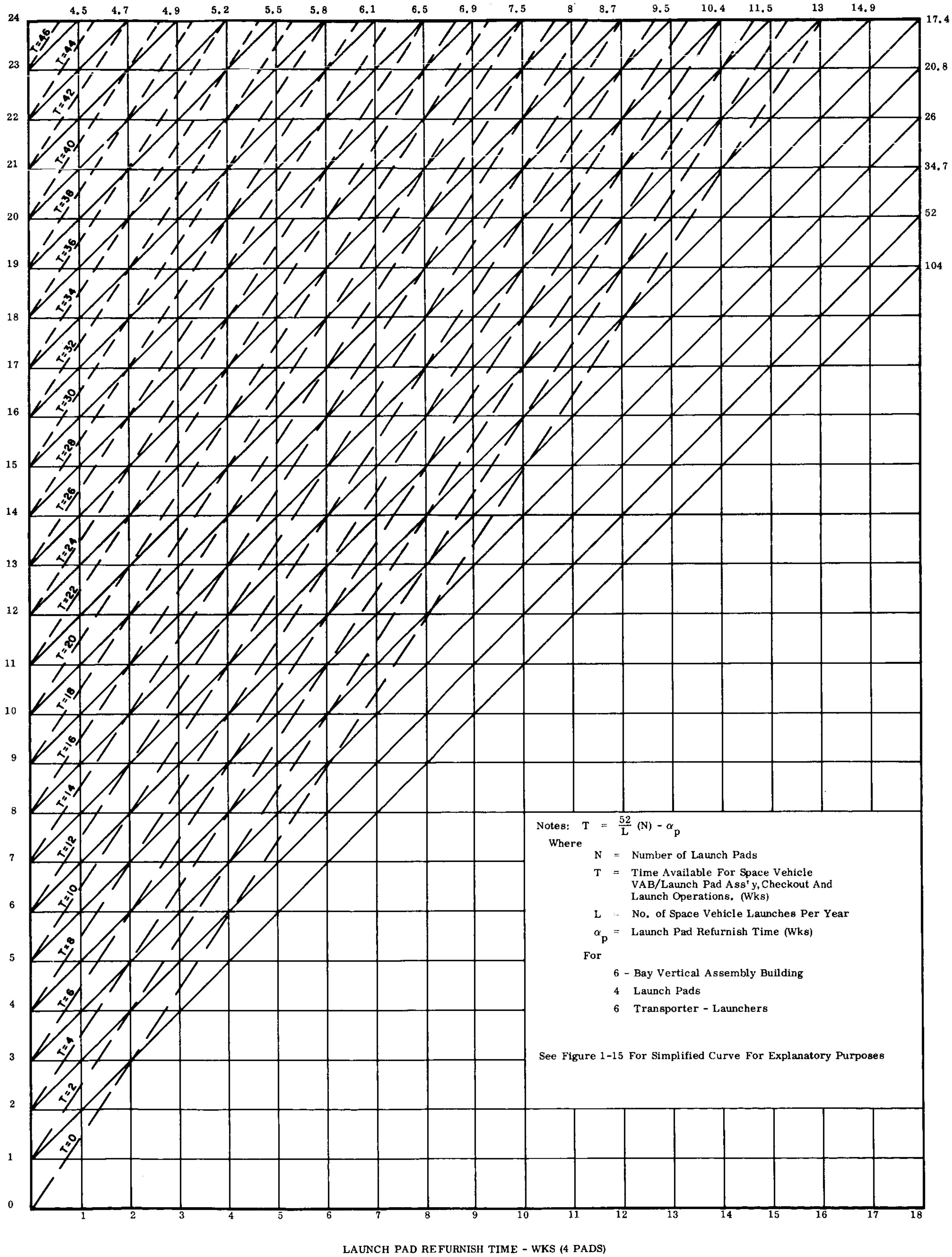


Figure 1-14. Basic Relationships Between Available Time - T - (for Vertical Assembly Building/Launch Pad Operations), Pad-Refurbish Time, and Launch Rate

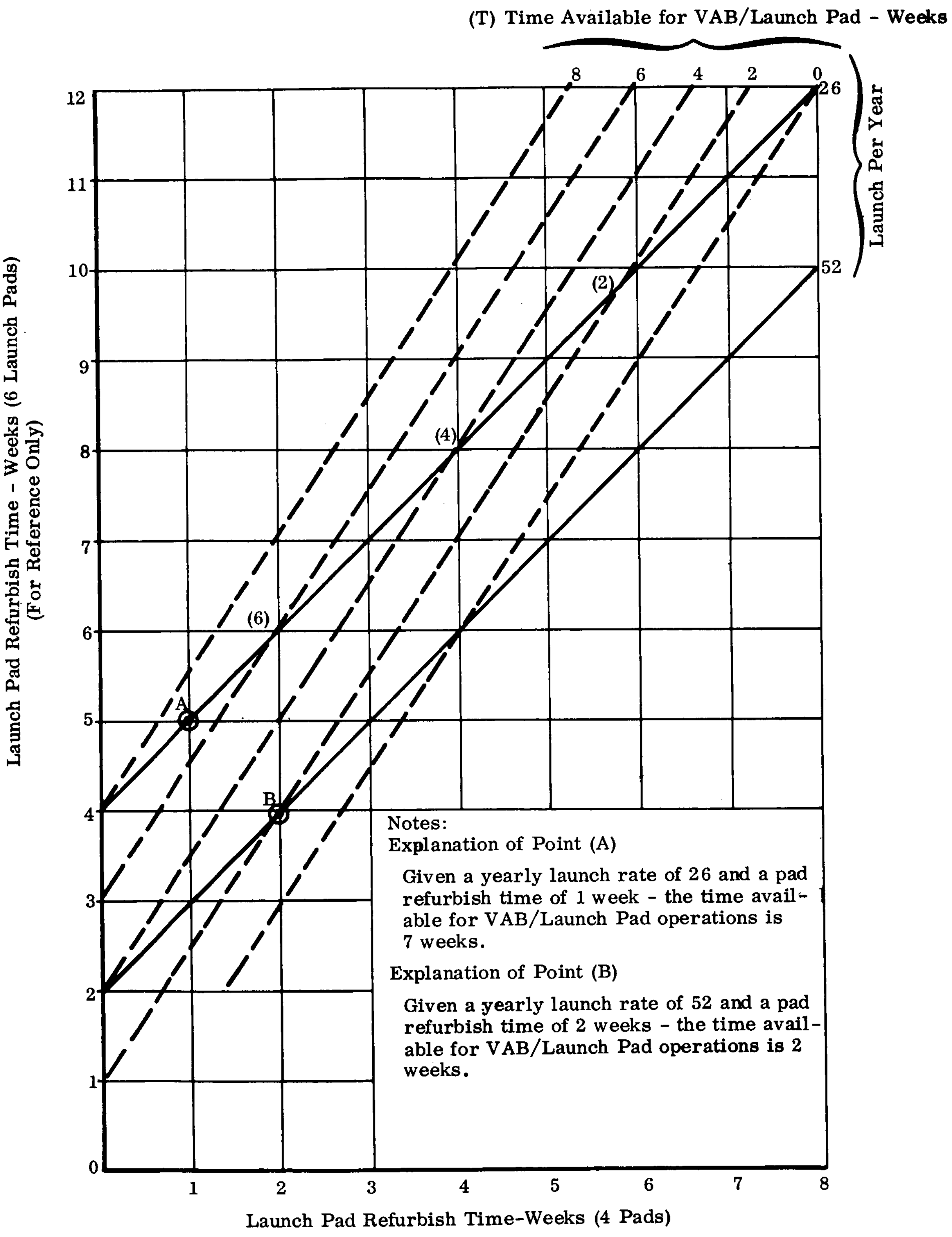
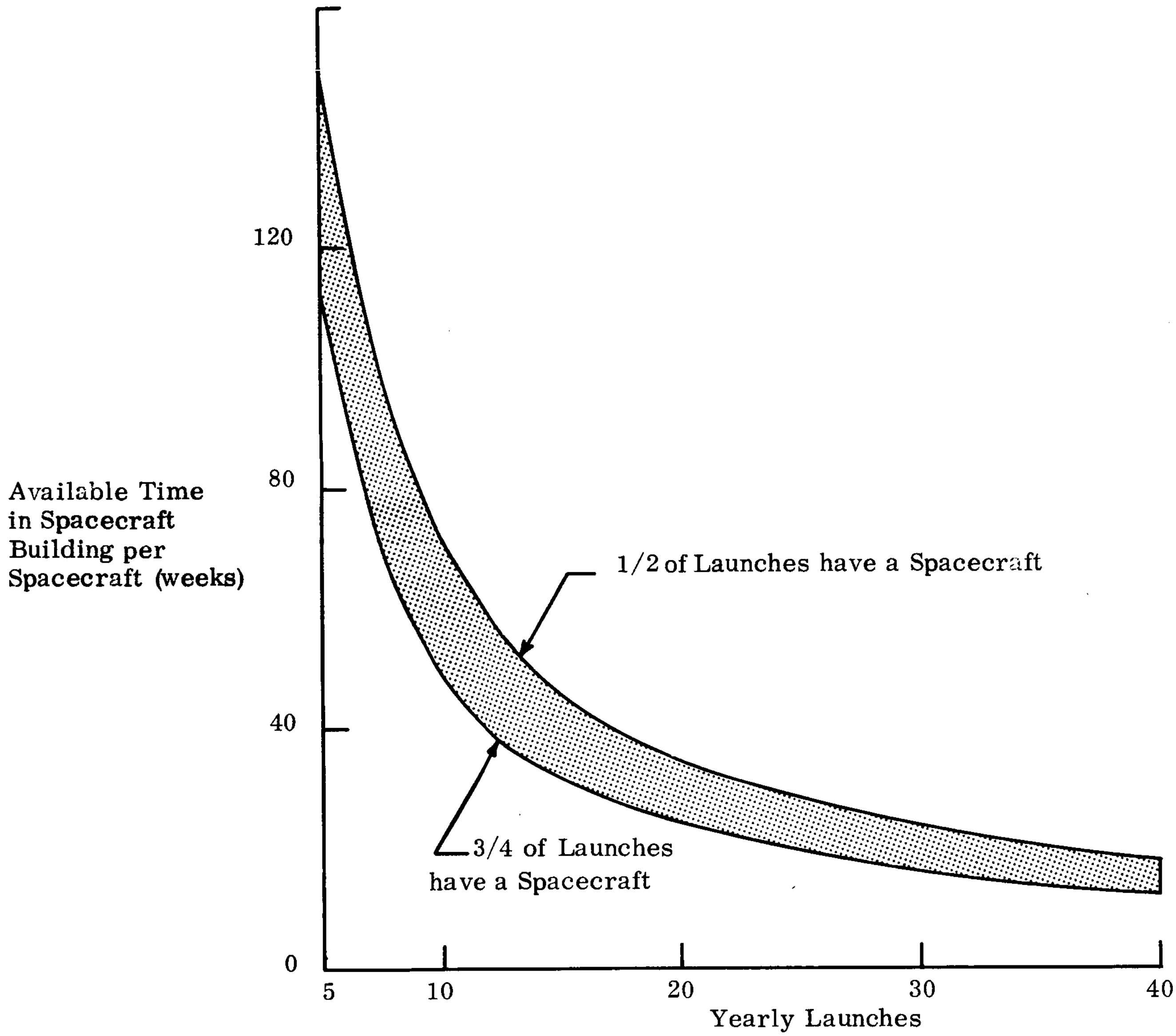


Figure 1-15. Expanded View of Basic Relationships Between Time, Launch Rate, and Pad-Refurbish Time for 26 to 52 Launches Per Year



Assumptions:

Seven Spacecraft Cells in Spacecraft Building

Figure 1-16. Time Allotted for Each Spacecraft in Order to Maintain a Yearly Launch Rate

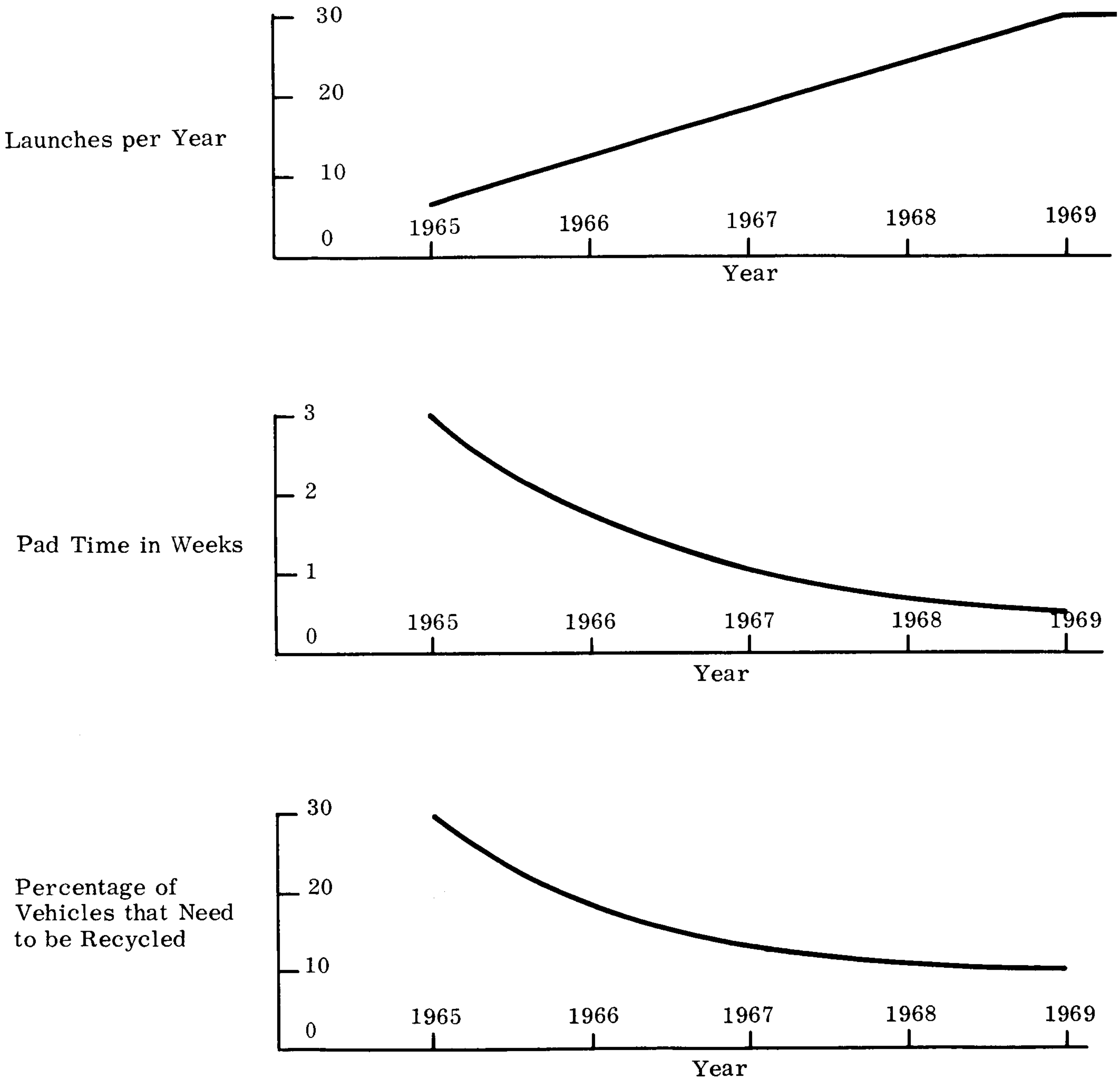
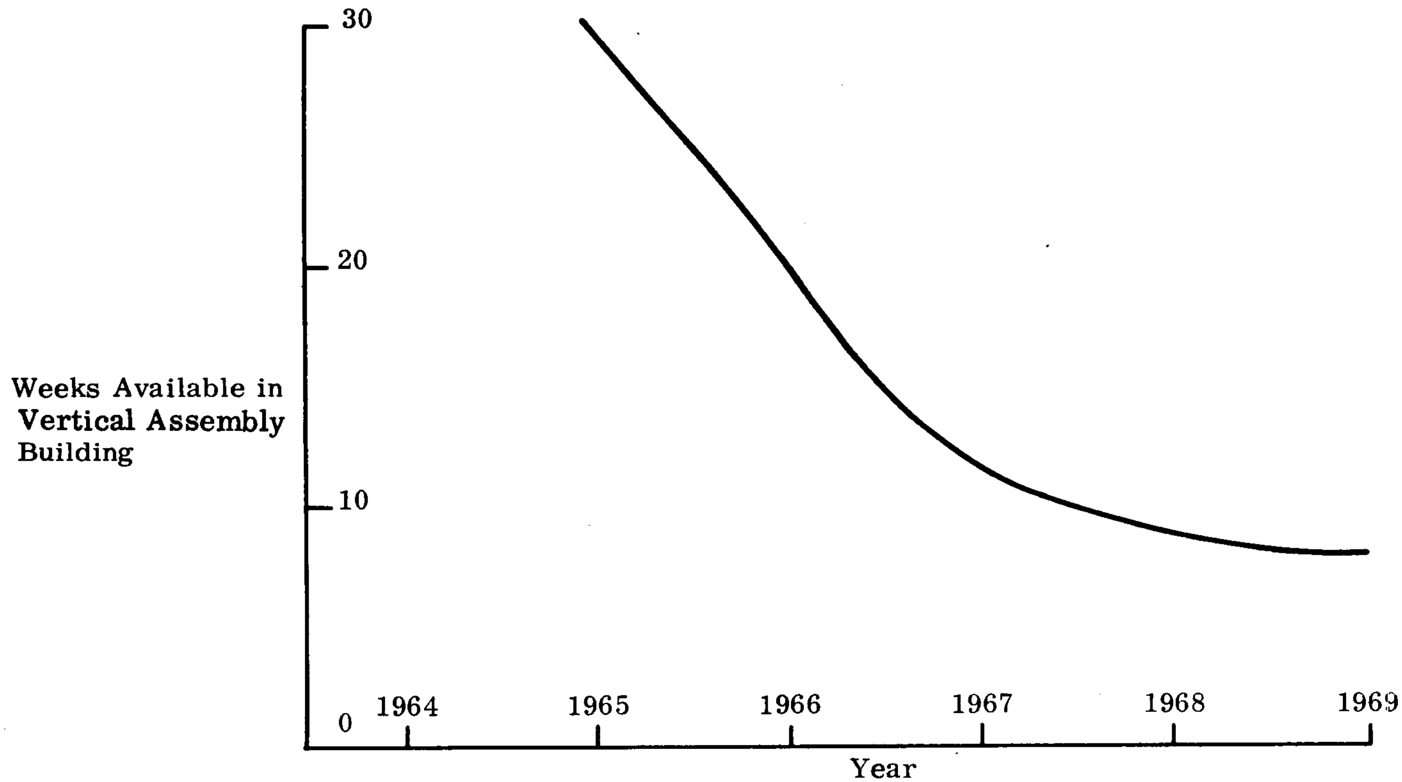


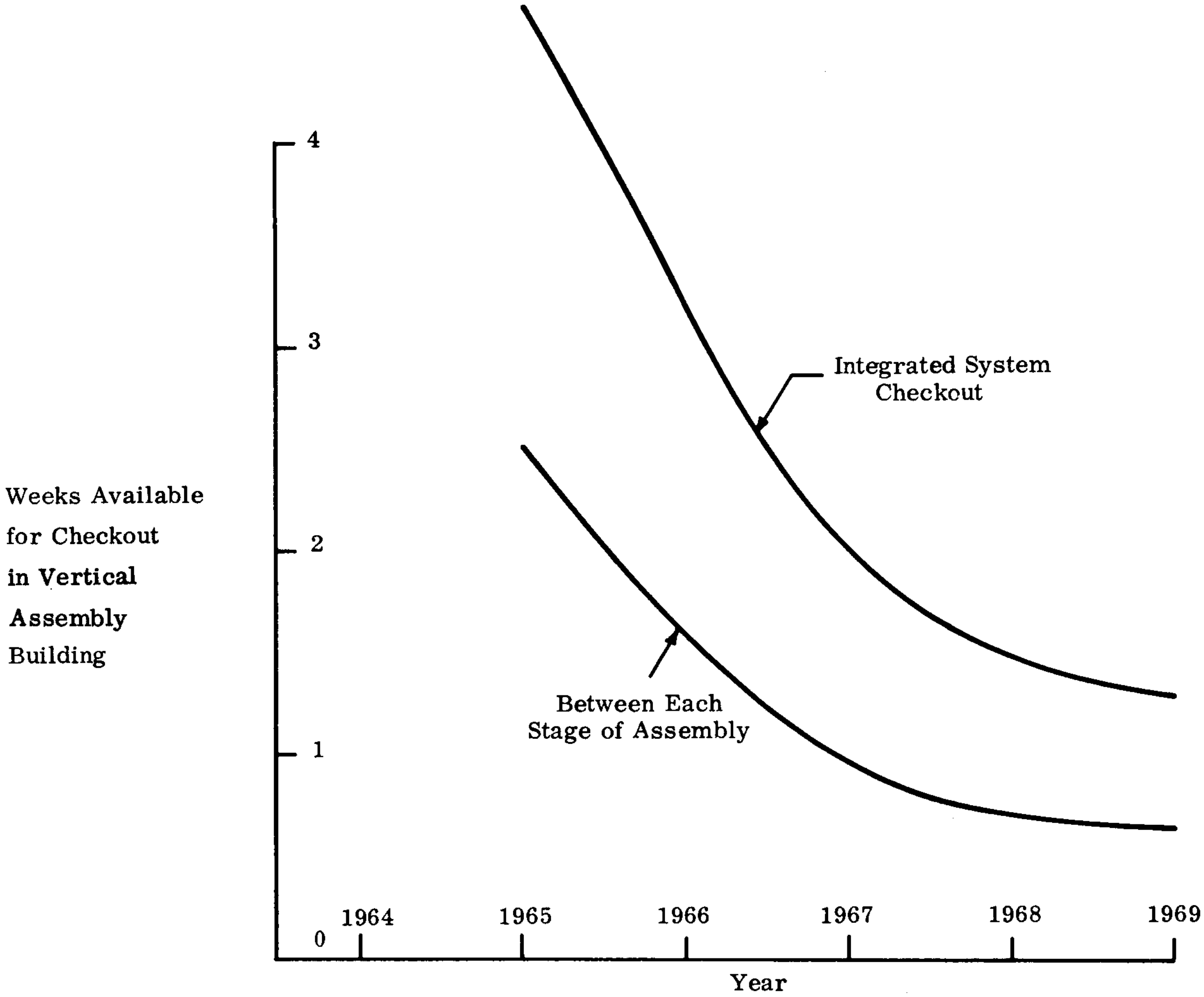
Figure 1-17. Curves of Assumptions Concerning Launch Schedules and Learning Curves



ASSUMPTIONS:

Pad Refurbish Time = 1 week
No Vertical Assembly Building Setup Time
Vertical Assembly Building Setup Time = 0.1 week
Curves in Figure 5-8

Figure 1-18. Weeks Available in the Vertical Assembly Building as a Function of the Year



ASSUMPTIONS:

Checkout between each assembly stage takes twice as long as the Assembly. Three Integrated Systems Checkouts. Systems Checkout takes twice as long as Stage Checkout.

Figure 1-19. Corresponding Times Allotted for Checkout

The available times presented above are the maximum times that can be expected for checkout. These times will be further reduced by normal delays, vehicle malfunctions on the pad, delayed shipments of new stages, delays associated with transport refurbish time, and so forth.

The analysis, thus far, leads to the following conclusions:

- The maximum checkout times available are quite modest in the light of the vehicle complexity.
- It makes little difference where the integrated vehicle checkout is done as far as the available time is concerned.
- The insensitivity to launch distribution shows that the checkout times available are insensitive to such missions as rendezvous versus direct ascent, C-1 versus C-5 versus Nova, and manned versus unmanned flights.

As additional information and data become available, further analysis will be performed. Of particular interest is a detailed time, motion, and procedures study of the space-vehicle assembly, checkout and launch cycle. The usefulness of the study will depend upon the determination of realistic times for the accomplishment of assembly, testing, calibration, measurement, alignment, simulation, and countdown functions.

SECTION 2
INTEGRATED CHECKOUT SYSTEM

2.1 INTRODUCTION

The integrated checkout system must provide continuous space vehicle data suitable for decisions relative to the probability of mission success for the period from space vehicle assembly through the initial flight phase. It must accomplish this with the utmost checkout-equipment reliability and checkout-data quality, while satisfying the requirements dictated by the Apollo and related program launch rates. It must provide sufficient operational flexibility for control and checkout of any Apollo mission configuration from the Vertical Assembly Building through launch. The capability of automatic or manual checkout control should be available, as required, by the Apollo research and development programs.

The integrated checkout system performs the function of identifying failures or problems which may limit the launch success. It is intended to be a tool for the test director and staff to expedite prelaunch testing and monitoring. The utilization of the integrated checkout equipment will be under the direction of the Launch Operations Center personnel.

An integrated system for checkout and control of space-vehicle assembly, prelaunch, and launch operations provides a centralized and unified control and serves to minimize interface problems which usually occur between completely separate and independent subsystems. It also provides for increased equipment reliability and simplification through design standardization. Centralized and uniform controls and displays simplify procedures and methods. A complex program, such as Apollo, requires a close-knit operation to coordinate the great numbers of interrelated functions.

The implementation plan described here provide over-all control of the checkout operations from assembly through launch from the Launch Control Center. All operations are easily controlled and monitored by the test director, through the use of appropriate communications and displays. The test director and staff can easily pass on related information from "outside" sources to the assembly and launch control areas, using the same facilities.

2.1.1 TESTING AND CHECKOUT PROGRAMS

The testing and checkout programs performed by the integrated checkout system should be limited to those deemed essential for space-vehicle assembly and prelaunch verification. Detailed testing related to the launch vehicle stages and spacecraft modules, performed before space-vehicle assembly, should not be completely repeated during assembly. To prevent excessive functional degradation due to wear, the frequency and extent of checkout activities will be determined by the space-vehicle reliability, emergency requirements, and from checkout-data evaluation. Complete control of launch-operations testing will be supervised and directed by the Launch Control Center Test Director and staff.

Correction of malfunctions detected by the integrated checkout system during assembly and detailed stage-equipment realignment will be the responsibility of the cognizant NASA center and associated contractor.

The format of the data obtained at the integrated checkout system and that obtained at factory and assembly areas must be compatible to aid historical data comparisons. The checkout equipment with which all of this data is obtained should be at least functionally identical, if not identical in design.

Checkout data will be relayed through a data distribution center to a checkout data-evaluation center for historical data comparison and checkout reprogramming as required. The integrated checkout system will be capable of accepting variable program sequences as designated by the data-evaluation center.

2.1.2 SYSTEM DESIGN

The integrated checkout system equipment should be designed for easy maintenance, and minimum sparing; wherever possible, off-the-shelf, proven components should be used.

The integrated checkout system should be designed for ease of operation with aids provided for training through mission simulation. The computation and data handling system should have a self-checking capability to assure data quality. The integrated checkout system equipment should have sufficient flexibility of design to offer growth potential and to satisfy the checkout requirements of any space vehicle similar to Apollo. This can be accomplished by modular design and flexible computer programming.

Some system rules, which should be applied to enhance the operation, display, and maintenance programs, are:

- Checkout programs and routines should be written and thoroughly checked before being employed.
- The complete assembly checkout and launch checkout programs should be controlled from a common center.
- All checkout data should be recorded, and all assembly and maintenance operations logged for evaluation.
- All assembly and prelaunch checkout data should be recorded in a common format.
- Uniform display and control configurations and methods should be used throughout.
- The same checkout stimuli and measurement checkout equipment should be used from assembly in the Vertical Assembly Building to launch.
- The design of the integrated checkout equipment should be standardized.

2.2 CHECKOUT OPERATIONS PHILOSOPHY

2.2.1 SCOPE

The scope of integrated checkout operations includes those activities from the initiation of assembly in the Vertical Assembly Building through the initial flight phase. The scope of operations also includes the preparation of appropriate computer programs. Consideration is given as well to the integration of the several associated agencies, including the Mission Control Center and the Atlantic Missile Range.

2.2.2 PHILOSOPHY

Automated tests of space-vehicle subsystems are performed during and after assembly of the space vehicle in the Vertical Assembly Building. During assembly, a vehicle checkout system is used to perform assembly inspection and tests. This includes equipment such as stage simulators and substitutes, located at various levels in the associated Vertical Assembly Building bay, which are necessary to check out each stage or module and combinations thereof.

All checkout operations are the responsibility of the test director and staff. Periodic meetings between the assembly and launch control personnel may be held in a Launch Operations Control Center to discuss an assembly or test program. Status data will be displayed and updated continually.

After assembly and initial checkout, with the spacecraft crew in their positions, a simulated mission would be run, in coordination with the Mission Control Center on an accelerated time scale. All subsystems would be exercised in the order of their use. Data on the response of the subsystems would be compared with limits, in the Launch Control Center, that have been established by previous testing of the individual subassemblies, and a decision made on the go or no-go status of the vehicle. Upon detection of a no-go condition, detailed testing would isolate the fault and a correction would be made. When all subsystems are in the go condition and the Mission Control Center is ready to proceed with a mission, the Launch Control Center orders the transporter-launcher moved to the Ordnance Tower for installation of pyrotechnic devices. After installation of pyrotechnics and testing the transporter-launcher travels to the launch pad. During the prelaunch sequence at the launch pad, subsystem tests become less complex and finally reduce to passive monitoring.

2.3 FUNCTIONAL DESCRIPTION OF THE INTEGRATED CHECKOUT SYSTEM

2.3.1 INTRODUCTION

The integrated checkout system performs checkout operations at the launch pad, in the Launch Control Center, space-vehicle vertical assembly area (Vertical Assembly Building for Apollo and related missions), and all areas related to the launch operation. The integrated checkout system also includes a data-evaluation system (Checkout Data Evaluation Center). Other checkout functions required are those for launch support equipment and facilities located at the launch pad, ordnance tower, space-vehicle transporter-launcher, Vertical Assembly Building and Launch Control Center.

The integrated checkout system functional block diagram (Figure 2-1) displays the major functional components of the integrated checkout system and communication paths required for data flow and operations control required during the space-vehicle assembly and launch control periods. It is assumed that both assembly and launch operations will report to Launch Control Center headquarters for integrated program control. The assembly operation in each Vertical Assembly Building bay includes a bay assembly supervisor, whose function is to supervise the assembly program in his bay and report status to the Vertical Assembly Building supervisor and to the Vertical Assembly Building assembly status board. All checkout data during assembly is monitored and recorded at the mobile checkout subsystem. If unusual performance data occurs which requires evaluation using historical data, this evaluation will normally take place at the Checkout Data Evaluation Center. The Launch Control Center data-processing unit may be used in support of the assembly program when not occupied with a mission. During a mission, the Launch Control Center will be occupied with the real-time display and control of that mission. Since all historical data is stored in the Checkout Data Evaluation Center, it is likely that all operations and evaluations supported by this data will be made there.

The Launch Control Center has the capability of monitoring and controlling functions related to two space vehicles simultaneously. It is assumed that two space vehicles may be committed to a launch, with one providing backup support.

Facilities monitoring and communications are maintained with all (4) launch pads and the ordnance tower from the Launch Control Center. Communications are also maintained with the Mission Control Center and Atlantic Missile Range operations.

2.3.2 SYSTEMS

Integrated checkout includes the following systems (see Figure 2-2).

- Launch Control Center
- Vehicle Checkout System
- Checkout Data Evaluation Center
- Integrated Checkout System Maintenance Center
- Communications Net (Checkout data, voice, and television)

2.3.2.1 Launch Control Center

The Launch Control Center provides the monitor and control functions of the prelaunch program, following space-vehicle assembly, and the program for checkout, monitor, and control of the launch. The Launch Control Center is the central control point for communication with the outside functions related to the mission during this phase of the Apollo program.

2.3.2.2 Vehicle Checkout System

The vehicle checkout system is composed of the mobile checkout subsystem, stationary assembly checkout subsystem, and the Checkout Data Distribution Center, which support the space-vehicle assembly and launch control operations.

The mobile checkout subsystem provides functions related to checkout control and monitoring of the space vehicle from assembly to launch. The mobile checkout subsystem is capable of independently performing a complete simulated flight test. A mobile checkout subsystem is located aboard each transporter-launcher. The mobile checkout subsystem may be operated locally, or remotely from the Launch Control Center.

The stationary assembly checkout subsystem includes assembly inspection equipment, stage and module simulators, and other special checkout and maintenance test equipment.

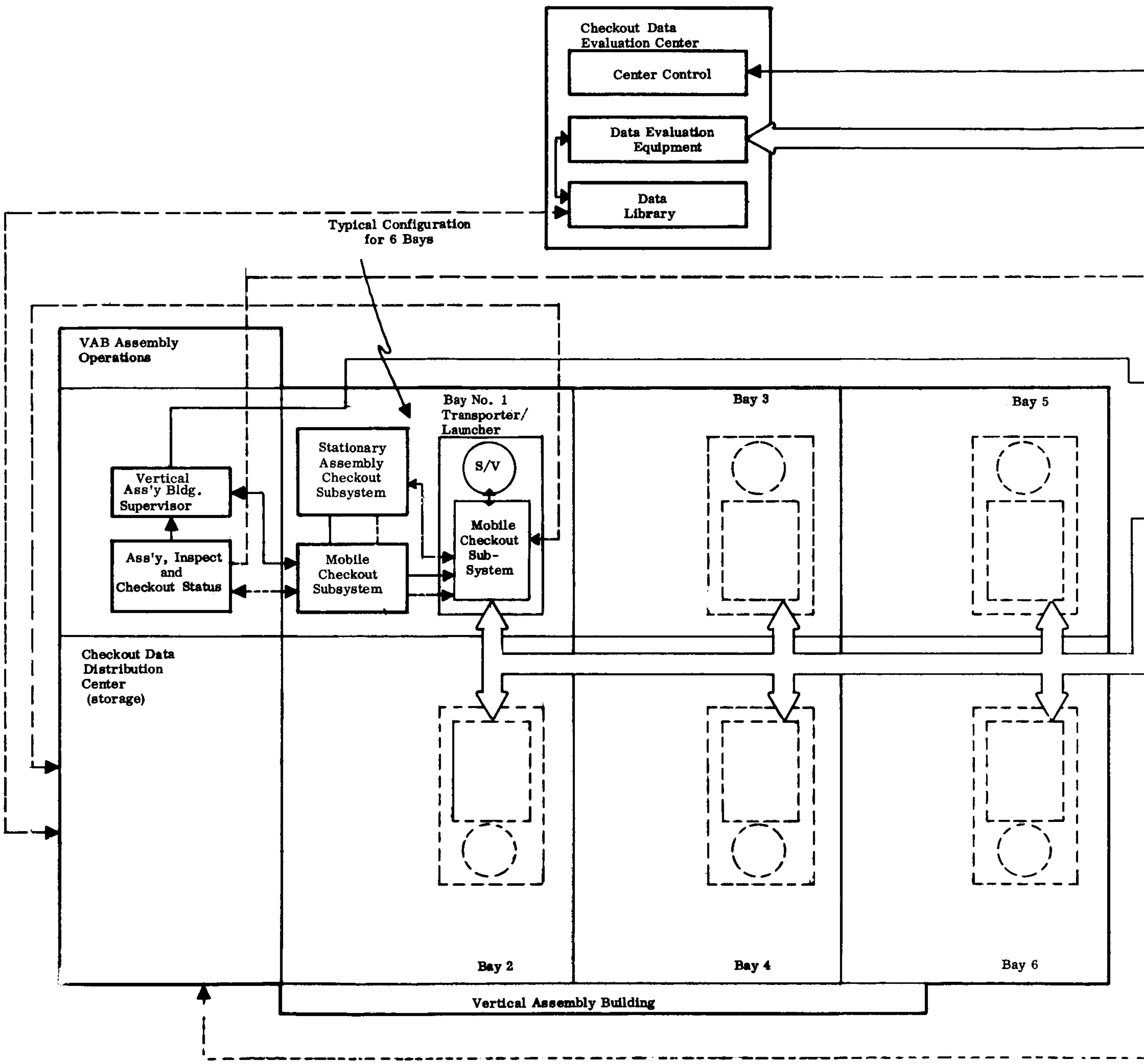
The Checkout Data Distribution Center performs a data library function. Checkout data and checkout programs going to and from the mobile checkout subsystem are stored there.

2.3.2.3 Checkout Data Evaluation Center

2.3.2.3.1 Introduction

The Checkout Data Evaluation Center is that portion of the integrated checkout system which provides analysis and/or interpretation of checkout information. The following paragraphs consider the external relationships and functional requirements of this evaluation center as a single facility; however, the desirability of physically separating the operation into a facility responsible for on-line, real-time interpretation of data in support of launch decisions, and a facility responsible for off-line, non-real-time evaluation and study of checkout data, is presently under consideration.

#1



Checkout Data Evaluation Center
Center Control
Data Evaluation Equipment
Data Library
Typical Configuration for 6 Bays
VAB Assembly Operations
Vertical Ass'y Bldg. Supervisor
Ass'y, Inspect and Checkout Status
Stationary Assembly Checkout Subsystem
Mobile Checkout Subsystem
Bay No. 1 Transporter/ Launcher
S/V
Mobile Checkout Sub-System
Bay 3
Bay 5
Checkout Data Distribution Center (storage)
Bay 2
Bay 4
Bay 6
Vertical Assembly Building

2

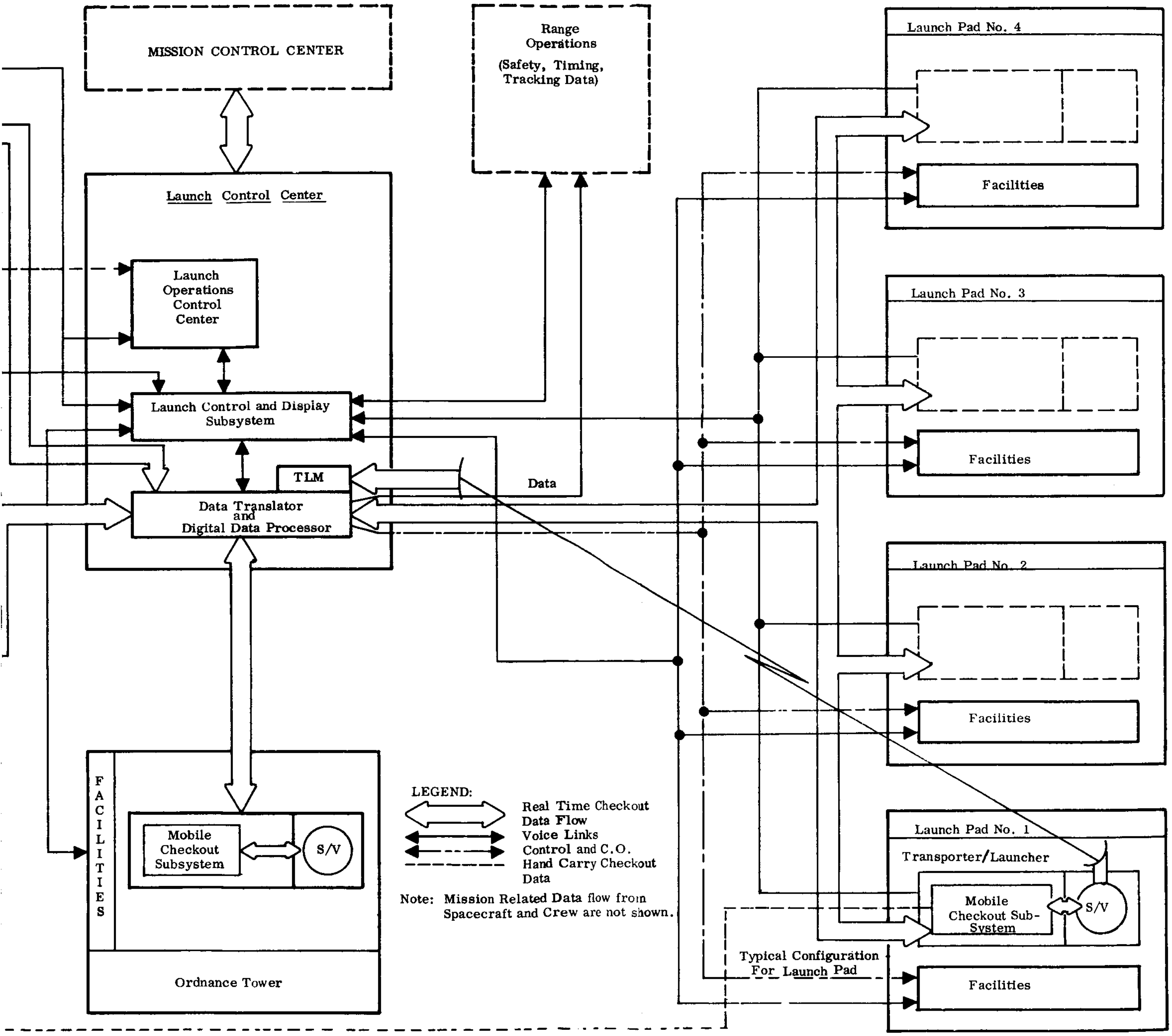


Figure 2-1. Integrated Checkout System Functional Block Diagram

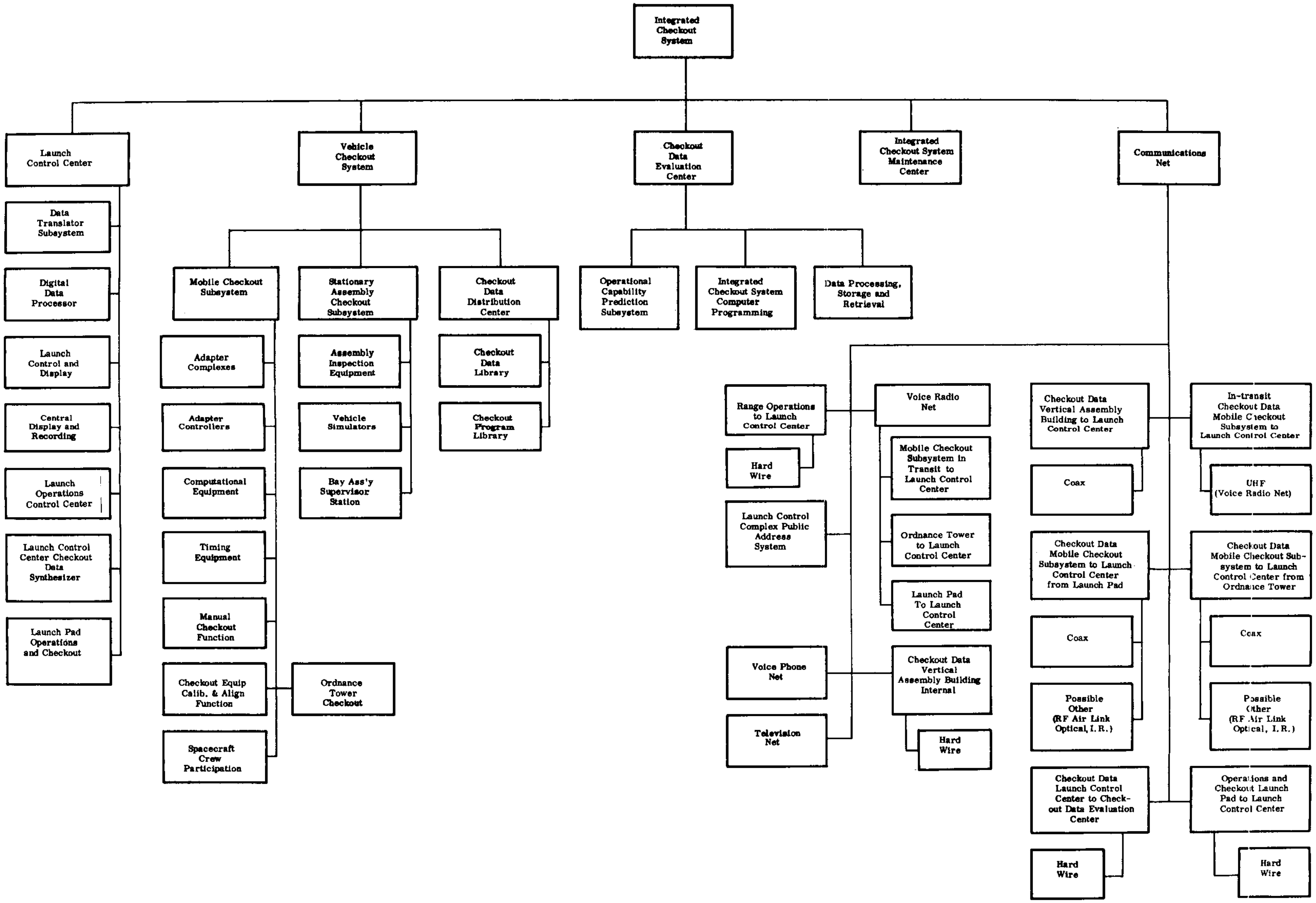


Figure 2-2. Integrated Checkout System Tree

2.3.2.3.2 External Relationships

The Checkout Data Evaluation Center is both a "data user" and a data source; it is therefore important to recognize and define the relationships to its various sources and "users." These relationships differ, depending upon the particular phase of the Apollo program. For example, a data source in one phase may become a "data user" in another phase. The five phases discussed below are: (1) design and development, (2) stage assembly and test, (3) vehicle integrated checkout, (4) post lift-off, and (5) post mission.

2.3.2.3.2.1 Design and Development

The prime sources of data during the design and development phase are the many contractors and subcontractors contributing to the Apollo program; the three prime "users" are the Manned Spacecraft Center, the Marshall Space Flight Center, and the Checkout Data Evaluation Operation. The Manned Spacecraft Center and the Marshall Space Flight Center will use the information to generate the programs and procedures for the "stage assembly and test" of the spacecraft and launch vehicle; the Checkout Data Evaluation Operation will use the information to generate the program and procedures for the assembly (Vertical Assembly Building) and integrated space-vehicle checkout.

2.3.2.3.2.2 Stage Assembly and Test

During the stage assembly and test phase, the Manned Spacecraft Center and the Marshall Space Flight Center are both "users" and sources; "users" of the design and development test data which was stored for reference, and "sources" of the newly accumulated test data. Design change information received during this phase will be used by the Checkout Data Evaluation Operation to update the planning, programming and procedures for the assembly and integrated space-vehicle checkout.

2.3.2.3.2.3 Vehicle Integrated Checkout

The vehicle integrated checkout phase may be considered in two parts, the time in the Vertical Assembly Building when the space vehicle is being assembled, and the time from completed assembly through the initial flight phase.

During the assembly part of this phase, the Checkout Data Evaluation Center will provide "interpreted" information to the Launch Control Center, with respect to the status of the proceedings, and will provide historical data (results of tests performed during previous phases) to the "assembly personnel" on request.

During the prelaunch part of this phase, the Checkout Data Evaluation Center will be available to the Launch Control Center, on request, to provide real-time analysis and interpretation of data.

All data collected during the vehicle integrated checkout phase will be sent to the Checkout Data Evaluation Center for post-lift-off and post-mission analyses and/or interpretation as required.

2.3.2.3.2.4 <u>Post-Lift-Off</u>

Since the Checkout Data Evaluation Center has all the historical data on the tests, test results, and procedures, it will be on standby to assist the Mission Control Center, upon request, during the post-lift-off phase. Appropriate data accumulated during the mission will be returned to the Checkout Data Evaluation Center for post-mission analysis, as required.

2.3.2.3.2.5 <u>Post-Mission</u>

All data relating to a particular equipment configuration and mission will be stored at the Checkout Data Evaluation Center for analysis as required.

2.3.2.3.3 Functional Requirements

The Checkout Data Evaluation Center will provide three basic functions:

- Compile integrated checkout computer programs for the vehicle checkout system and Launch Control Center.
- Analyze and interpret test results to provide:
  a. Status information to the Launch Control Center
  b. Assistance to the Launch Control and Mission Control Centers on request
  c. Suggestions for test and/or equipment modifications
- Provide a test-data library.

2.3.2.3.4 Implementation

An immediate study will be undertaken to estimate the data-processing requirements for this data center; the study will seek to determine (1) the quantity of incoming data from NASA agencies and contractors, (2) the data storage and retrieval requirements, (3) the data-processing load (routine and special programs), and (4) the data reporting rates of the center. The functional equipment will include:

- Data-processing equipment (computer complex)
- Data control equipment
- Data conversion (abstracting and formatting) equipment
- Off-line storage and retrieval equipment
- Data transmission terminal equipment
- Data reproduction and distribution equipment

2.3.2.4 Integrated Checkout System Maintenance Center

The Integrated Checkout System Maintenance Center contains the test equipment and spares required to maintain the integrated checkout equipment.

2.3.2.5 Communications Net

The communications net is composed of the various links required to handle all checkout data, voice, and television communications within the integrated checkout system.

2.3.3 DATA FORMATS

Formats for all checkout data from factory to launch must be selected to minimize data transformation requirements and enhance the data-evaluation programs. The data obtained from the integrated checkout system will have a common format. A review of all data requirements will be made during a data-evaluation center requirements study with regard to the desired formats and methods of recording and transmitting. It is advisable to utilize the same data recording format at the spacecraft and launch-vehicle factory and test areas to minimize the need for format transformation at the Checkout Data Evaluation Center.

2.3.4 CHECKOUT FUNCTIONAL DESCRIPTION

The following paragraphs describe the space-vehicle checkout program, beginning with delivery of the launch vehicle and spacecraft components to the Vertical Assembly Building.

2.3.4.1 Space-Vehicle Assembly

A space-vehicle integrated checkout operation begins with the space-vehicle assembly in the Vertical Assembly Building. After delivery to the Vertical Assembly Building, the S-IC stage is inspected and erected on a transporter-launcher at a location assigned by the Launch Operations Center. Here it is checked out with the vehicle checkout system (the appropriate stage's simulator and other special equipment, and the locally operated mobile checkout subsystem) and with the appropriate assembly checkout program. Following the S-IC sign-off, the inspected S-II stage is assembled on the S-IC. The appropriate stage simulator is then employed with the mobile checkout subsystem to check out the S-II and S-IC/S-II combination. Careful attention and support will be given to the mating and checkout of the two stages by the cognizant representatives from the industrial contractors, NASA center, and Launch Operations Center to provide maximum assurance of reliability. A similar procedure will be employed for assembling and checking out the S-IVB stage, instrument unit, and spacecraft modules to complete the space-vehicle assembly. The checkout data from this operation will be recorded and stored in the Checkout Data Distribution Center for evaluation at Checkout Data Evaluation Center, and for review by the other NASA Centers.

2.3.4.2 Mission Simulation in the Vertical Assembly Building

Following the space-vehicle assembly and over-all checkout, a complete mission simulation test in the Vertical Assembly Building will be initiated from the Launch Control Center, in coordination with the Mission Control Center. The flight crew will be aboard the spacecraft, the mobile checkout subsystem manned, with the Launch Control Center controlling and monitoring the program. Control from the Launch Control Center will consist of ordering specific test routines and sequences to be performed by the mobile checkout subsystem. Data will be relayed from the mobile checkout subsystem to the Launch Control Center for monitoring and decision making, and also recorded at the mobile checkout system (this data as well as any repair records will be stored in the Checkout Data Distribution Center library for transmission to the Checkout Data Evaluation Center). This test insures proper over-all space-vehicle performance and that the procedures and equipment to be employed are functioning properly. The full mission simulation will be particularly important for assuring proper integration of tests and procedures related to unique mission or spacecraft component requirements. The space vehicle will then be secured and the checkout system placed in a monitor mode. In this mode, a checkout function is performed, only in the event of a malfunction indication. The space vehicle then awaits a command from launch operations to proceed to the ordnance tower.

2.3.4.3 Vertical Assembly Building to the Ordnance Tower

Local monitoring from the manned mobile checkout subsystem is maintained until the transporter reaches the ordnance tower. Communications are maintained between the mobile checkout subsystem and Launch Control Center via voice links during transit. At the ordnance tower, tests pertaining to functions performed there are made. The capability for performing other tests exists also, and the data relayed to the Launch Control Center by RF or hard-wire links.

2.3.4.4 Ordnance Tower to the Launch Pad

The manned mobile checkout subsystem is placed in the monitor mode during transit from the ordnance tower to the launch pad. Communications are maintained with the Launch Control Center via a voice communication link. The status of the transporter is monitored and relayed to the Launch Control Center via the same voice link.

2.3.4.5 Checkout at the Launch Pad

At the launch pad, the mobile checkout subsystem is again placed in the checkout mode, and a predetermined checkout program will be performed. This program may be different for two space vehicles of the same type because of previous checkout data evaluation and the possible differences in times until launch. Program variations may be ordered, as determined by the Launch Control Center test director. A program change constitutes selection of a particular stored routine or of a stored sequence of routines. Routines and sequences will not be generated in real time, but will be assembled and completely checked before storage in the mobile checkout subsystem computer or made available in the Checkout Data Distribution Center library (see Section 2.4). An accelerated flight (or mission) simulation test can be performed at this time with the mobile checkout subsystem providing stimuli and evaluating performance in accordance with a previously determined program coordinated with the Mission Control Center. The spacecraft will be manned for this test. Complete monitor data of the go/no-go variety is transmitted via coax data link to the Launch Control Center for continuous monitoring. Detailed quantitative data is relayed to the Launch Control Center upon request. Also, quantitative data may be relayed to the Checkout Data Evaluation Center via the Launch Control Center for mission capability prediction analysis. All test data are recorded at the mobile checkout subsystem and removed from the transporter-launcher when the transporter is evacuated before launch. These data are logged and stored in the Checkout Data Distribution Center library prior to distribution to the postflight data-evaluation centers.

Following transporter-launcher evacuation, the mobile checkout subsystem is operated remotely from the Launch Control Center. Launch-pad operations, such as fueling, LOXing, and launch sequencing are initiated and monitored at the Launch Control Center. The mobile checkout subsystem ceases checkout and monitoring at the time the adapters are disconnected from the space vehicle.

The launch sequence is initiated via a hard line. The command is applied from the Launch Control Center to the launch sequencing equipment located in the launch-pad configuration.

The space-vehicle tracking, telemetry, and communication links are monitored at the Launch Control Center, and Mission Control Center via the Ground Operational Support System, during the flight simulation tests. The telemetry links are made with the Launch Control Center before lift-off and continued through the flight boost phase where the Launch Control Center has responsibility. Ground Operational Support System data may be required to complete boost phase monitoring because of the distance of the vehicle from the Launch Control Center.

2.3.4.6 Functional Flow Diagrams

The functional flow diagrams (Figures 2-3 and 2-4) show the anticipated checkout and inspection functions occurring from the arrival of the space-vehicle components at the Cape receiving areas, through launch. These diagrams assume that hold conditions may occur, resulting in extension of the prelaunch time cycle and possibly requiring repair or return to the Vertical Assembly Building. This diagram does not show return of the transporter for refurbishing for future missions and alignments of sensors and checkout equipment. However, these functions do exist, but are not space-vehicle in-line checkout functions. Prelaunch operational functions in the Launch Control Center, Vertical Assembly Building, and Checkout Data Evaluation Center are omitted from the diagram for simplicity. Details on these areas appear in sections of this report directly related to these subsystems.

Another important prelaunch function is removal of the transporter crew and locally recorded checkout data. This function occurs at the end of the launch-pad safety period. From this time on, the mobile checkout subsystem is under complete control of the Launch Control Center. The data removed includes all automatic checkout recorded data from tests and monitoring and all manual inspection and checkout records.

The sequence of the prelaunch test procedures described here appears elsewhere in this report. The purpose of this is to provide a prelude which will enable the reader to more clearly understand the equipment function described in that section.

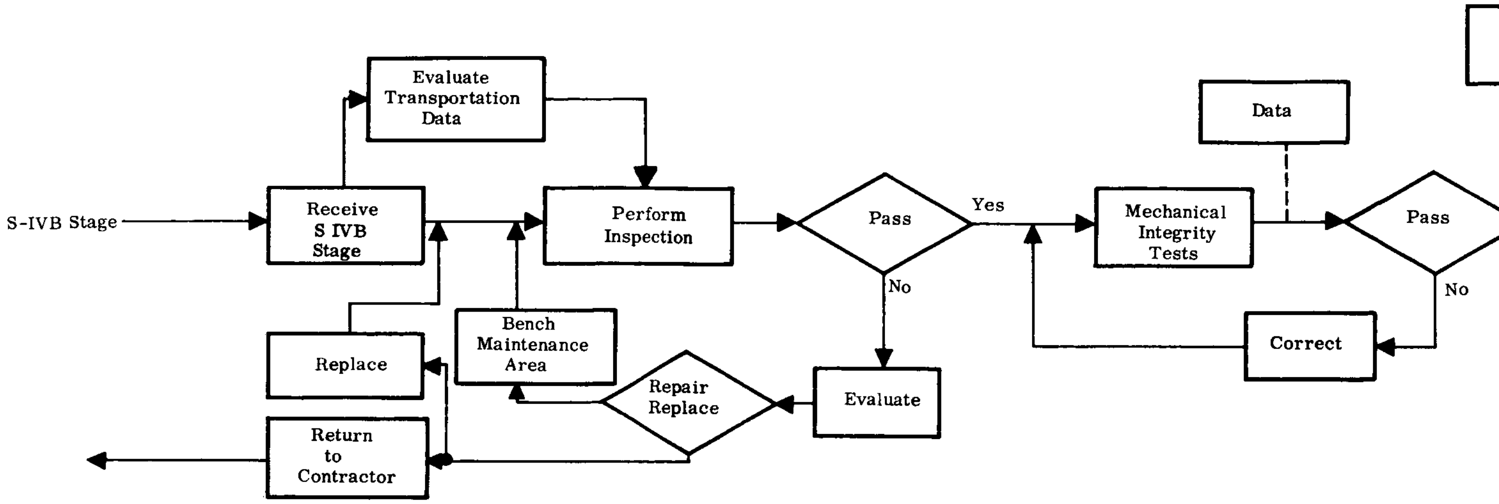
2.3.5 DEGREE OF TESTING

Normal integrated checkout, after space-vehicle assembly, is end-to-end point testing and monitoring of all space-vehicle functions pertinent to mission success. However, the mobile checkout subsystem has the capability for providing fault-location analysis. An ideal diagnostic program would provide fault isolation down to a readily removable black-box level. The degree to which this is practical is contingent on the availability of the data required for analysis. This entails complete knowledge of symptoms that indicate malfunctions. A comprehensive study, in conjunction with the cognizant NASA centers and design contractors, is necessary to identify these symptoms. Another factor which plays an important part in the implementation of an ideal diagnostic program is the practicability of obtaining the required data. Consideration must be given to the complexity of the data sensing and conversion equipment requirements. This is a subject for detailed study.

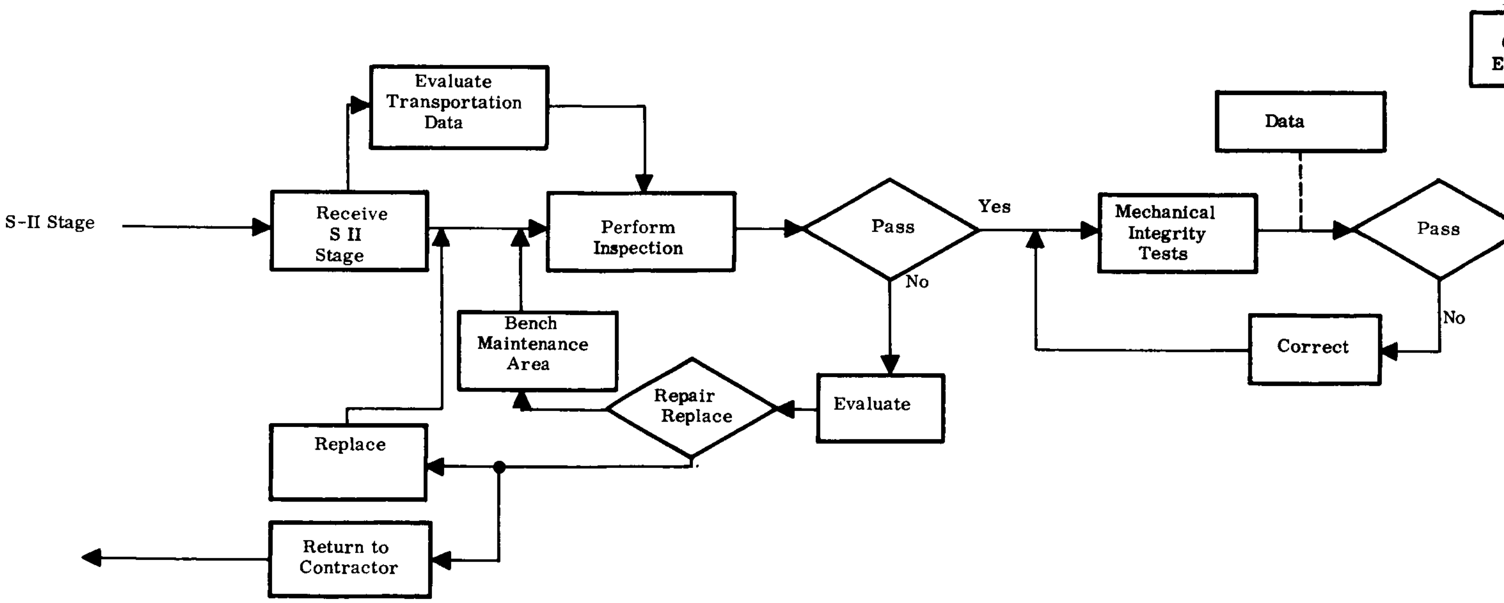
2.3.6 DECISION DURING HOLDS

The decision to repair on-pad or return to the Vertical Assembly Building will be determined by the seriousness of the fault, and the time, personnel, and complexity of the maintenance equipment required. The decision will be made at the Launch Control Center with the aid of a predetermined listing of faults and estimated complexity of associate repair programs.

#1

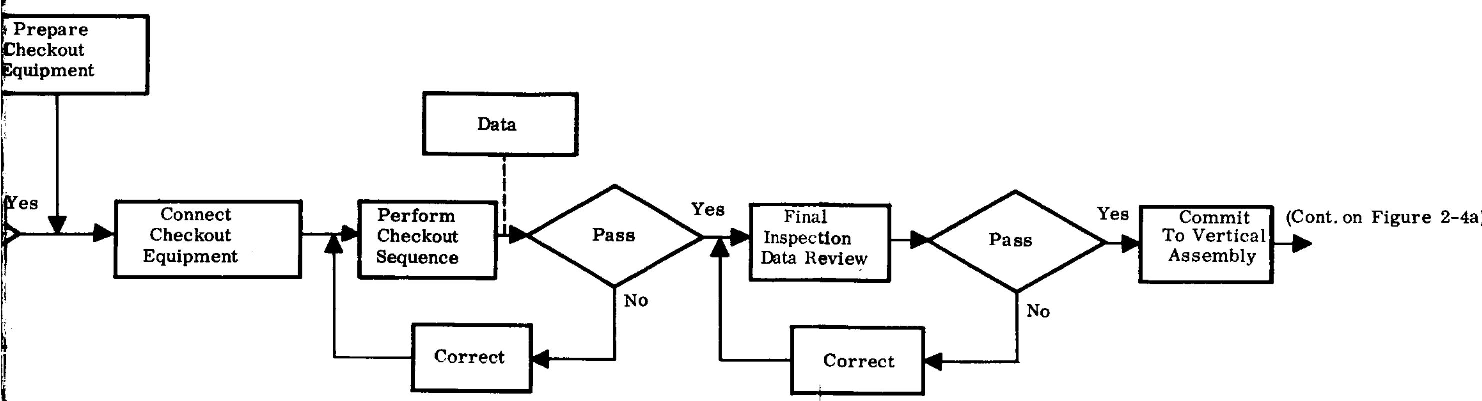


S-IVB Stage
Receive
S IVB
Stage
Evaluate
Transportation
Data
Perform
Inspection
Pass
Yes
No
Mechanical
Integrity
Tests
Data
Pass
No
Correct
Evaluate
Repair
Replace
Bench
Maintenance
Area
Replace
Return
to
Contractor



S-II Stage
Receive
S II
Stage
Evaluate
Transportation
Data
Perform
Inspection
Pass
Yes
No
Mechanical
Integrity
Tests
Data
Pass
No
Correct
Evaluate
Repair
Replace
Bench
Maintenance
Area
Replace
Return to
Contractor

#2



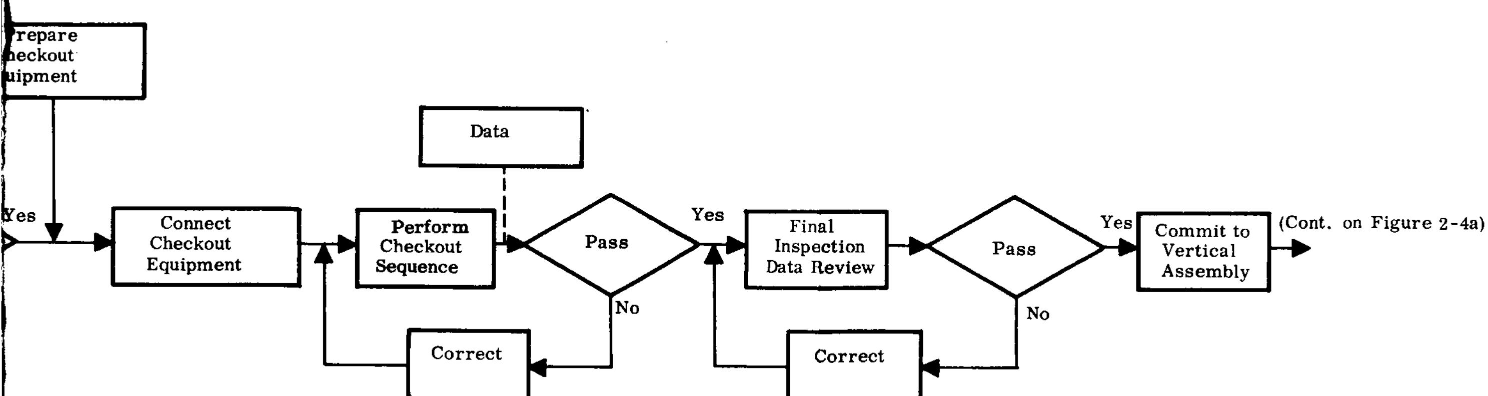


Figure 2-3. Assembly Logic Block Diagram Through Arrival at Vertical Assembly Building

a. S-II Stage and S-IV Stage Arrival at AMR to Vertical Assembly

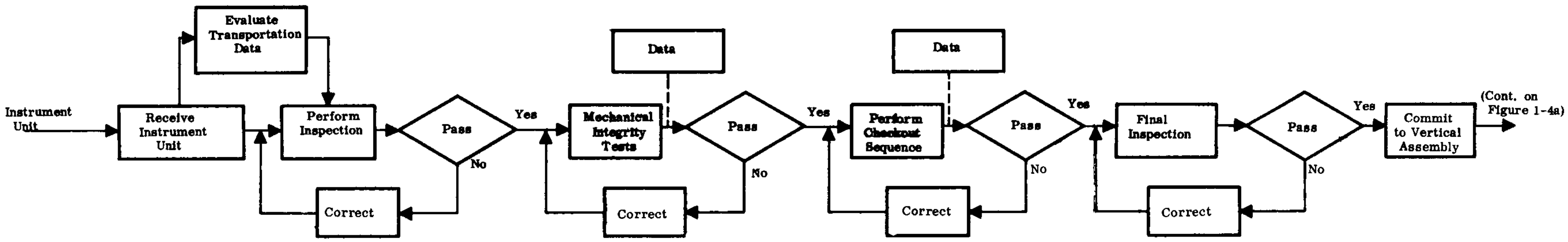
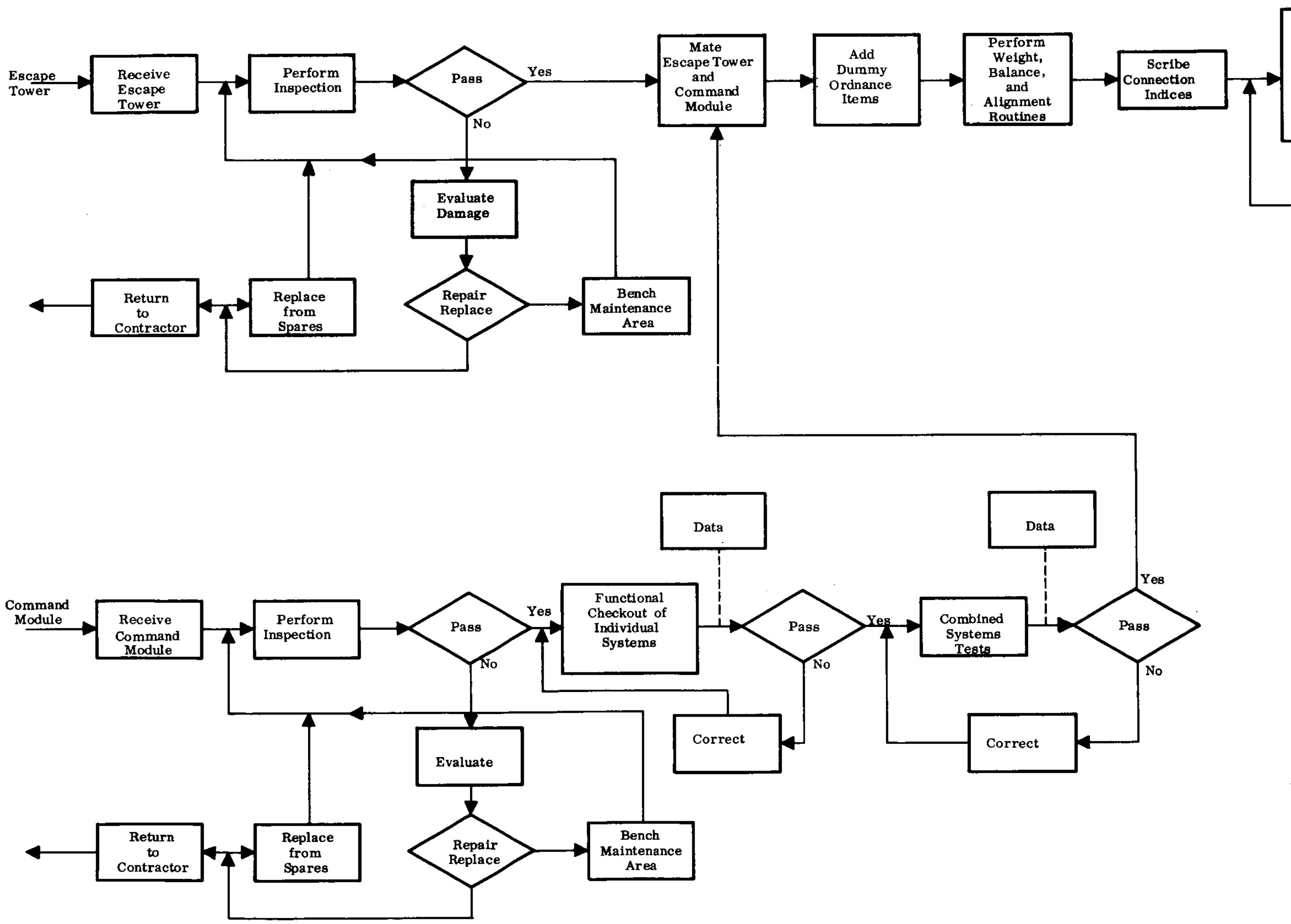


Figure 2-3. Assembly Logic Block Diagram Through Arrival at Vertical Assembly Building

b. Instrument Unit Arrival at AMR to Vertical Assembly

#/



Escape Tower
Receive Escape Tower
Perform Inspection
Pass
Yes
No
Mate Escape Tower and Command Module
Add Dummy Ordnance Items
Perform Weight, Balance, and Alignment Routines
Scribe Connection Indices
Evaluate Damage
Return to Contractor
Replace from Spares
Repair Replace
Bench Maintenance Area
Command Module
Receive Command Module
Perform Inspection
Pass
Yes
No
Functional Checkout of Individual Systems
Data
Pass
Yes
No
Combined Systems Tests
Data
Pass
Yes
No
Correct
Correct
Evaluate
Return to Contractor
Replace from Spares
Repair Replace
Bench Maintenance Area

#2

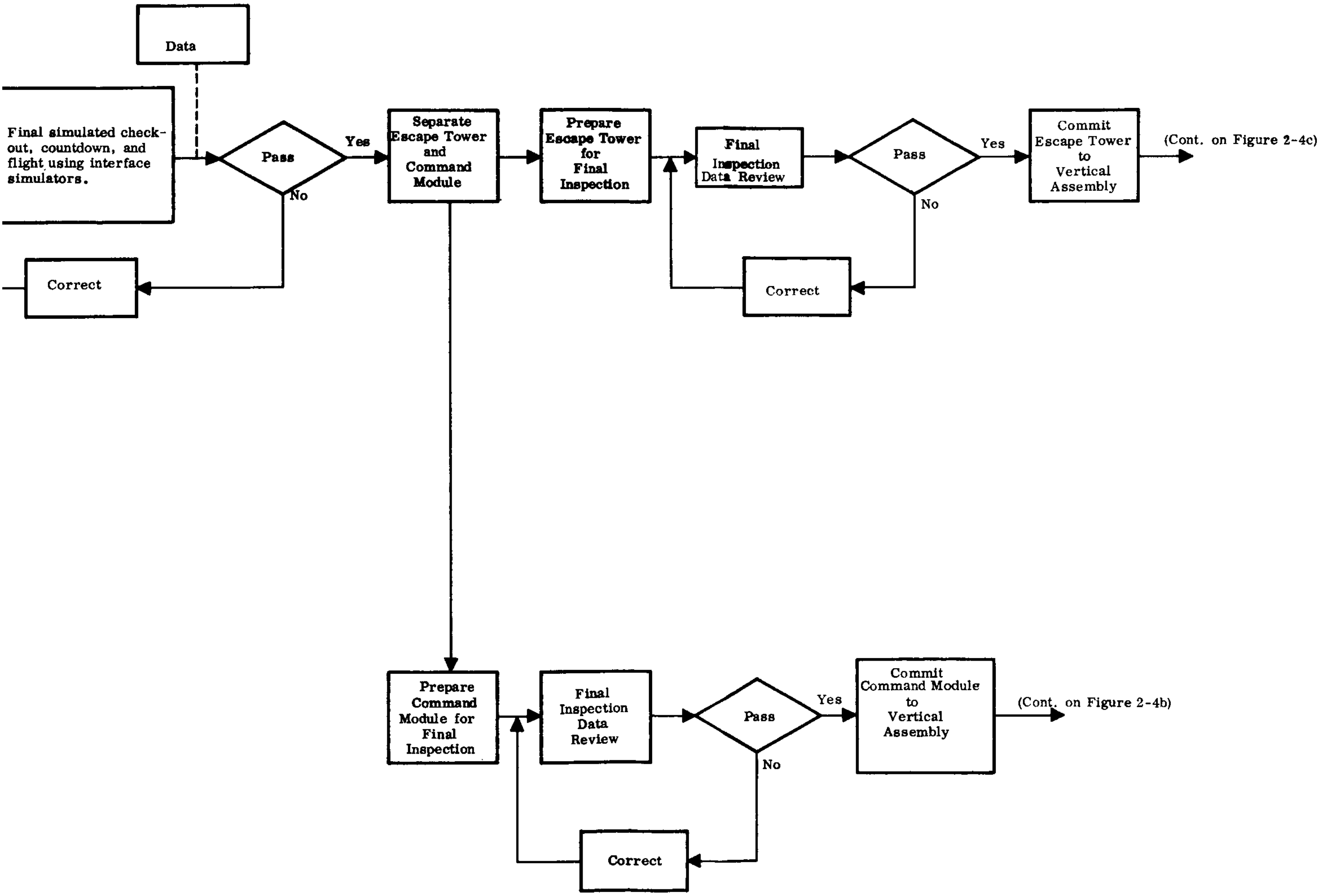
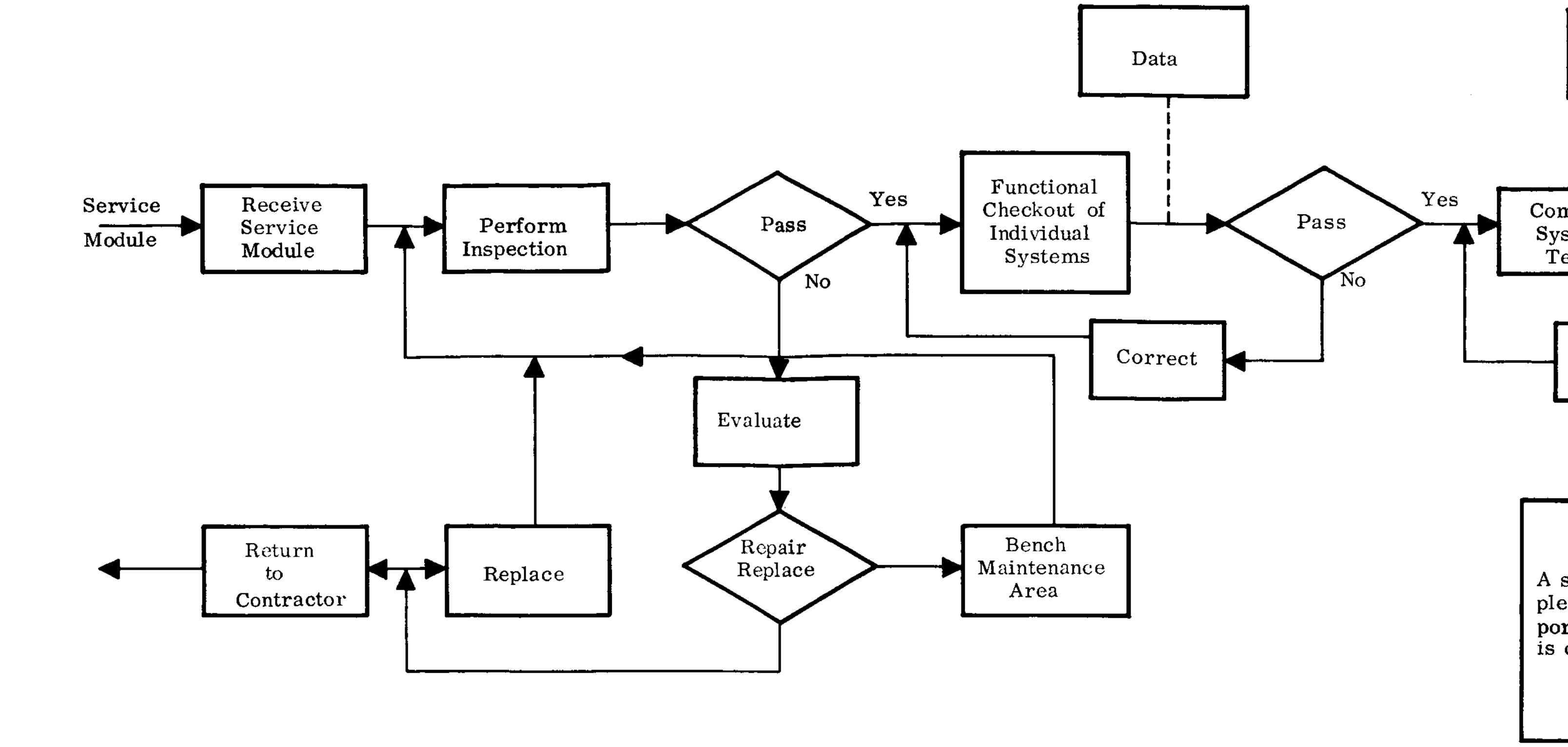
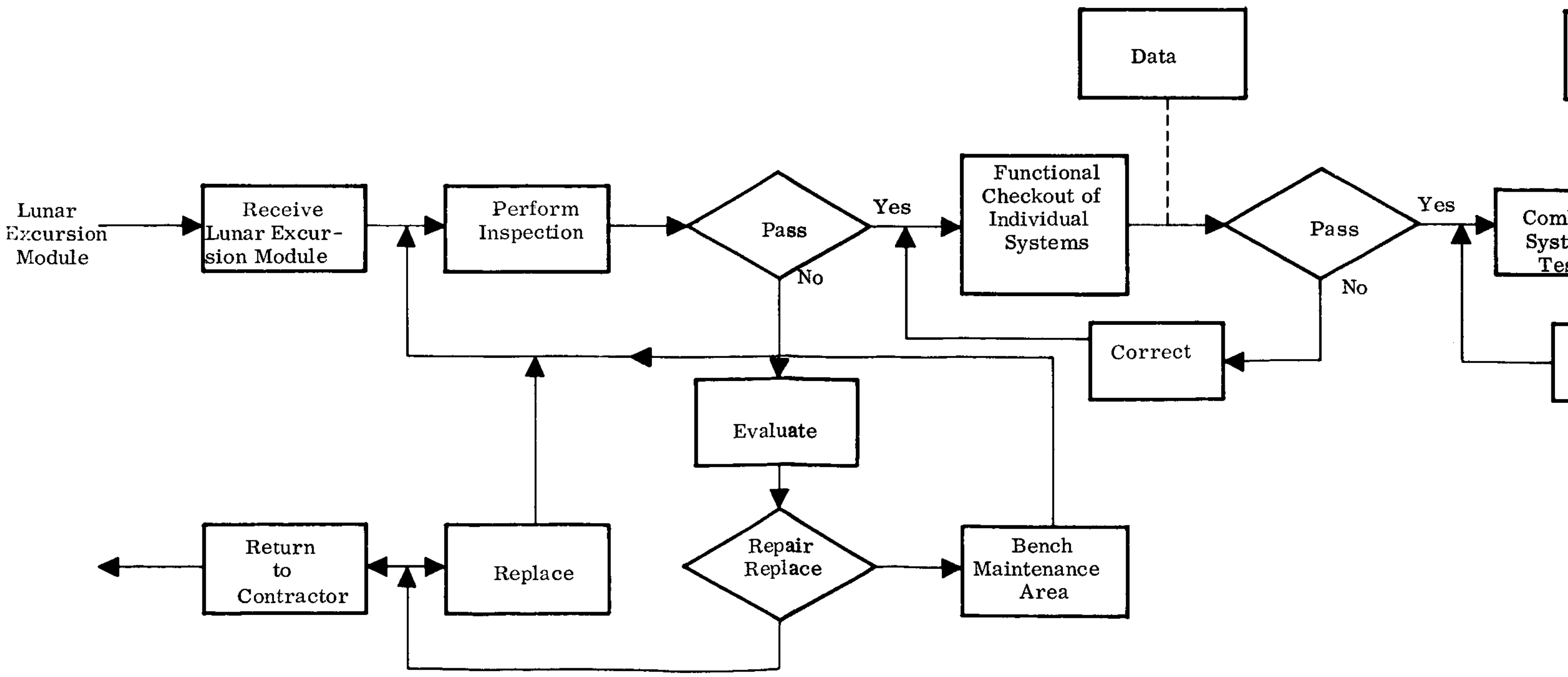
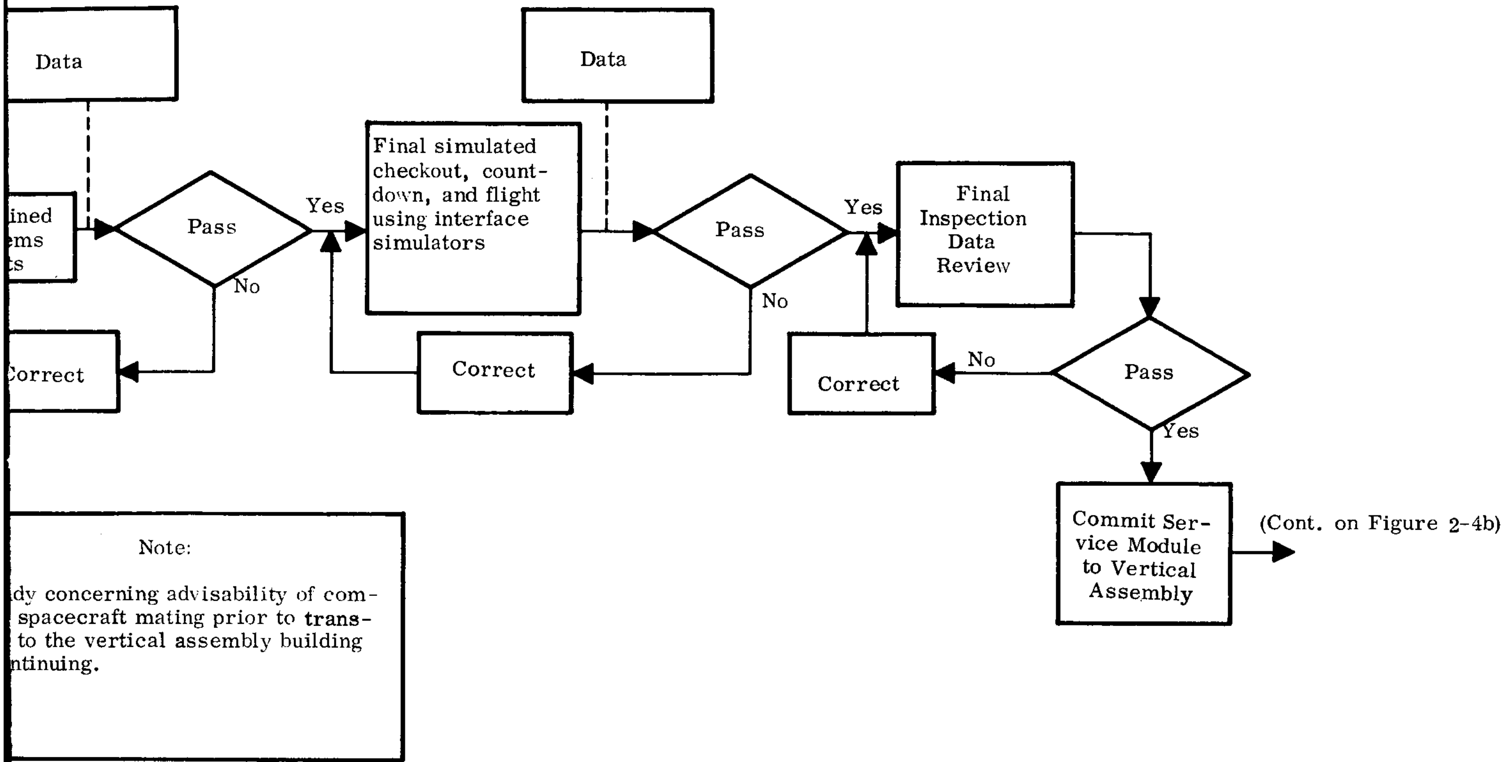


Figure 2-3. Assembly Logic Block Diagram Through Arrival at Vertical Assembly Building

c. Escape Tower and Command Module from Arrival at AMR to Vertical Assembly


Service Module
Receive Service Module
Perform Inspection
Pass
Yes
No
Data
Functional Checkout of Individual Systems
Pass
Yes
No
Correct
Evaluate
Repair Replace
Bench Maintenance Area
Return to Contractor
Replace


Lunar Excursion Module
Receive Lunar Excursion Module
Perform Inspection
Pass
Yes
No
Data
Functional Checkout of Individual Systems
Pass
Yes
No
Correct
Evaluate
Repair Replace
Bench Maintenance Area
Return to Contractor
Replace



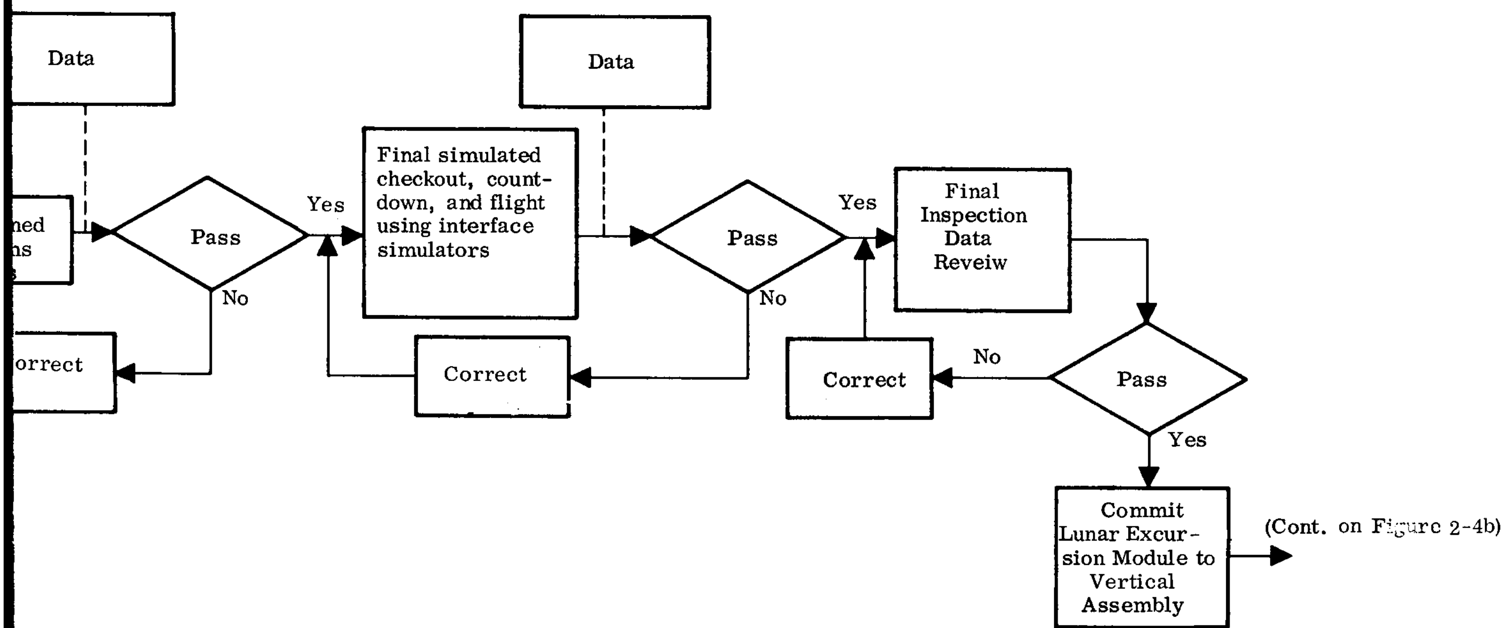
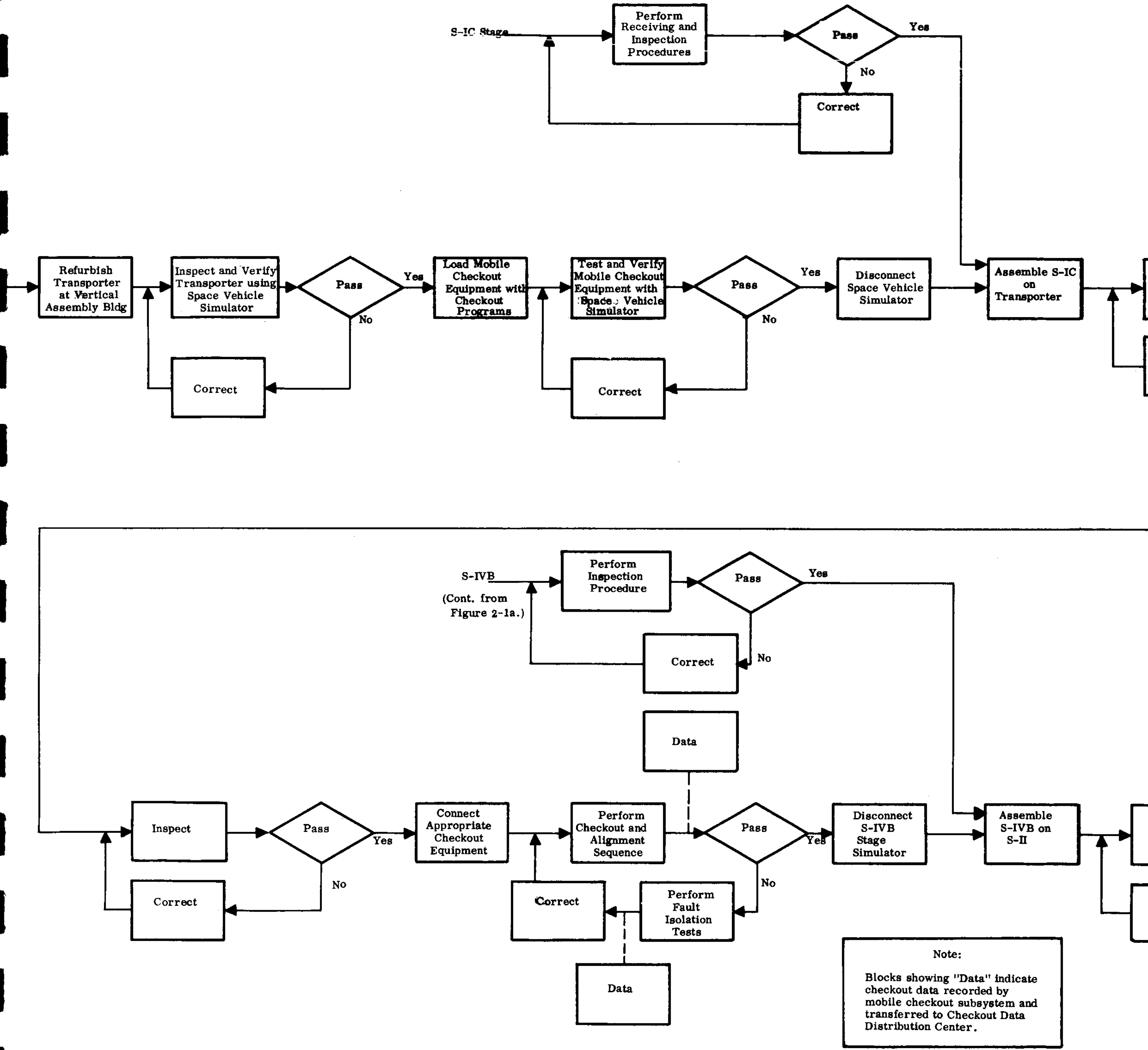


Figure 2-3. Assembly Logic Block Diagram Through Arrival at Vertical Assembly Building

d. Service Module and Lunar Excursion Module Arrival at AMR to Vertical Assembly

#/



S-IC Stage
Perform Receiving and Inspection Procedures
Pass
Yes
No
Correct
Refurbish Transporter at Vertical Assembly Bldg
Inspect and Verify Transporter using Space Vehicle Simulator
Pass
Yes
No
Correct
Load Mobile Checkout Equipment with Checkout Programs
Test and Verify Mobile Checkout Equipment with Space Vehicle Simulator
Pass
Yes
No
Correct
Disconnect Space Vehicle Simulator
Assemble S-IC on Transporter
S-IVB
(Cont. from Figure 2-1a.)
Perform Inspection Procedure
Pass
Yes
No
Correct
Data
Inspect
Pass
Yes
No
Correct
Connect Appropriate Checkout Equipment
Perform Checkout and Alignment Sequence
Pass
Yes
No
Disconnect S-IVB Stage Simulator
Assemble S-IVB on S-II
Correct
Perform Fault Isolation Tests
Data
Note:
Blocks showing "Data" indicate checkout data recorded by mobile checkout subsystem and transferred to Checkout Data Distribution Center.

#2

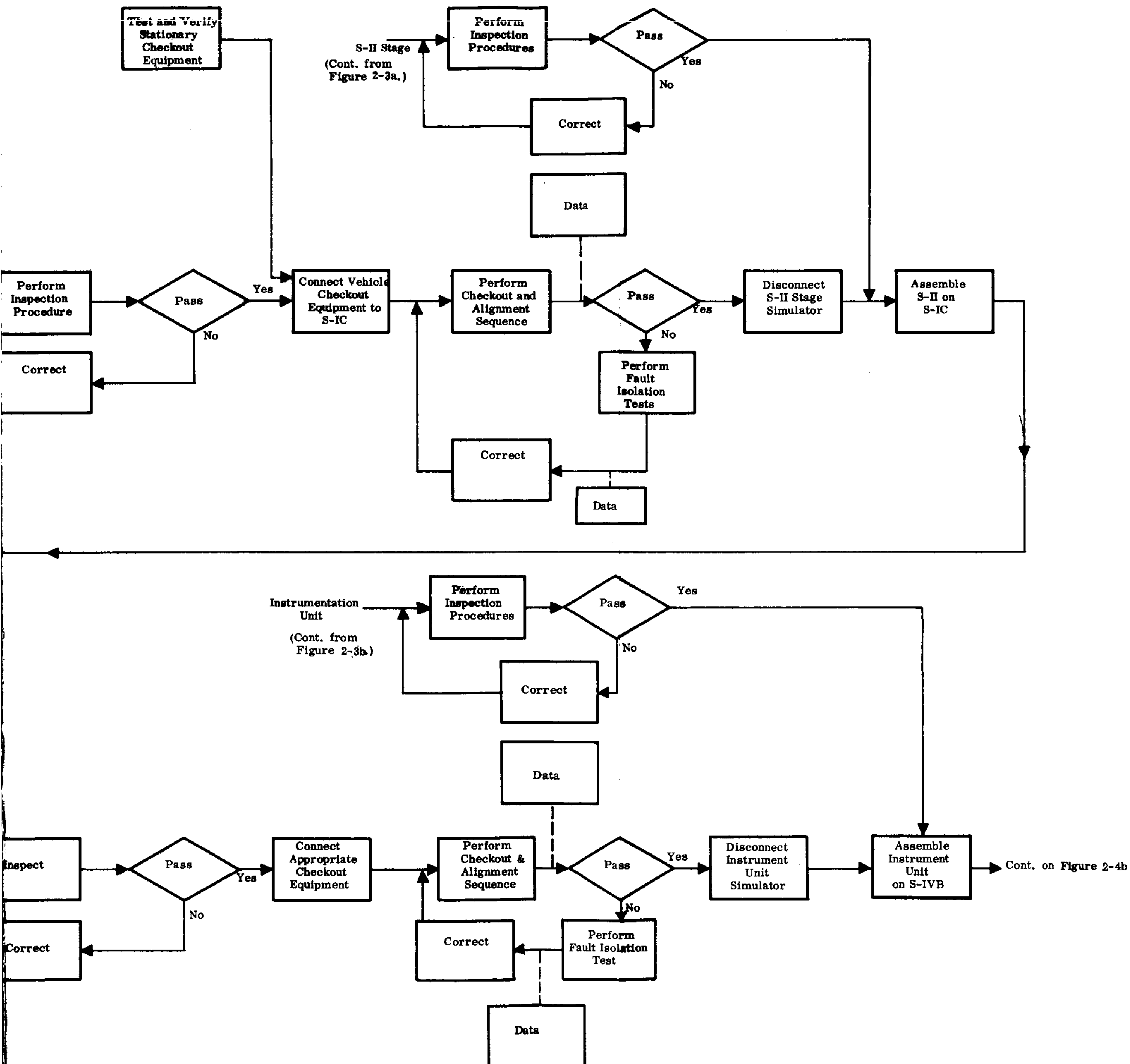
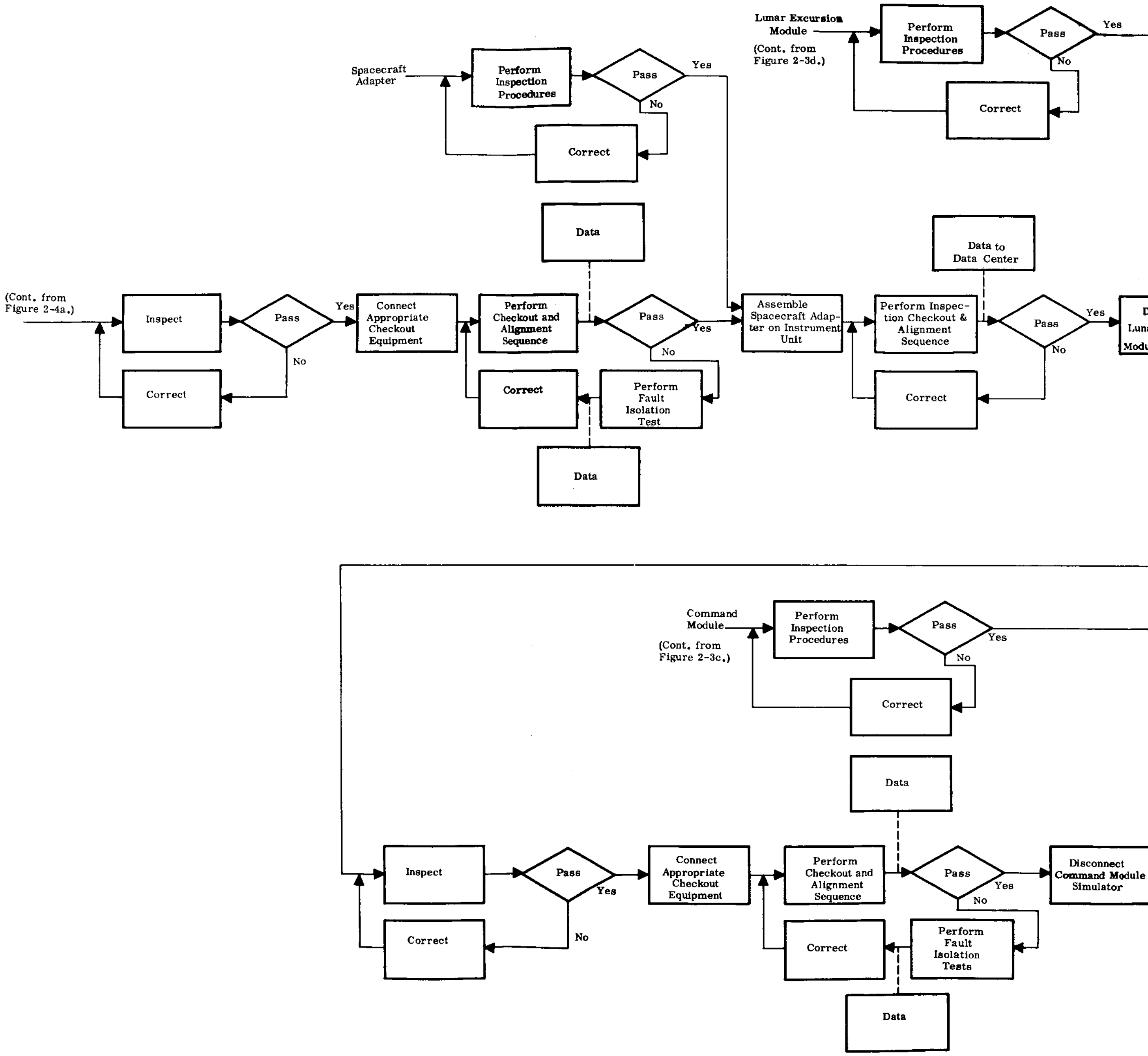
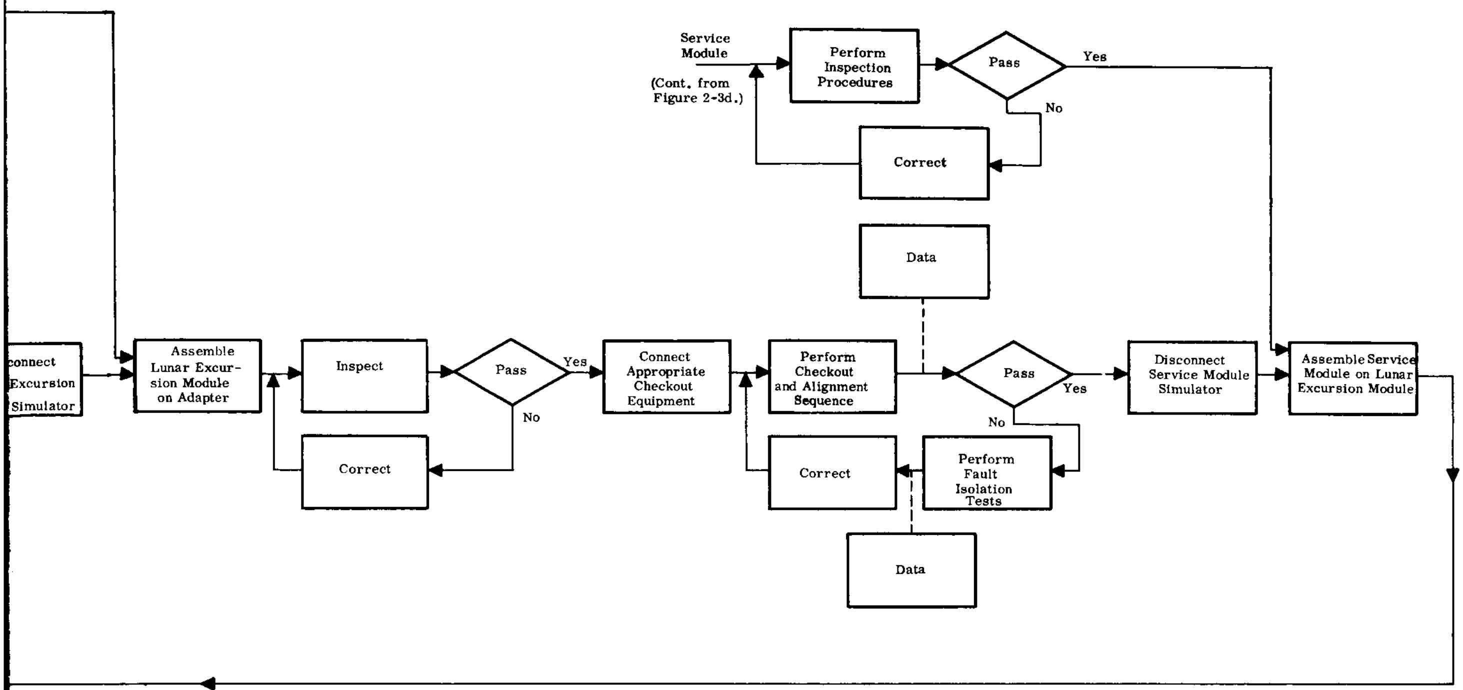


Figure 2-4. Vehicle Assembly Checkout Logic Block Diagram

a. Space Vehicle Assembly - Receipt of S-I Stage at AMR Through Assembly of Instrument Unit



Lunar Excursion Module
(Cont. from Figure 2-3d.)
Perform Inspection Procedures
Pass
Yes
No
Correct
Spacecraft Adapter
Perform Inspection Procedures
Pass
Yes
No
Correct
Data
Data to Data Center
(Cont. from Figure 2-4a.)
Inspect
Pass
Yes
No
Correct
Connect Appropriate Checkout Equipment
Perform Checkout and Alignment Sequence
Pass
Yes
No
Correct
Perform Fault Isolation Test
Data
Assemble Spacecraft Adapter on Instrument Unit
Perform Inspection Checkout & Alignment Sequence
Pass
Yes
No
Correct
Command Module
(Cont. from Figure 2-3c.)
Perform Inspection Procedures
Pass
Yes
No
Correct
Data
Inspect
Pass
Yes
No
Correct
Connect Appropriate Checkout Equipment
Perform Checkout and Alignment Sequence
Pass
Yes
No
Correct
Perform Fault Isolation Tests
Data
Disconnect Command Module Simulator



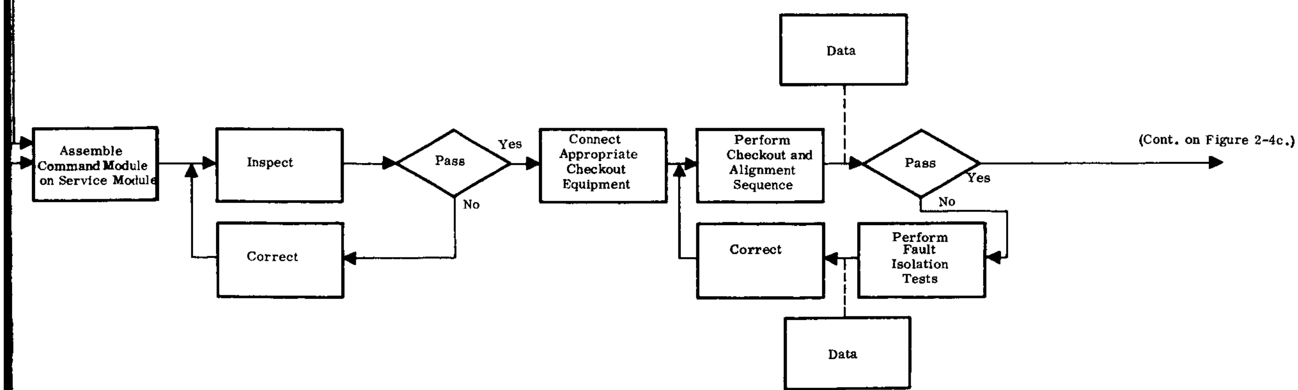


Figure 2-4. Vehicle Assembly Checkout Logic Block Diagram

b. Space Vehicle Assembly - Instrument Unit Through Assembly and Checkout of Command Module

#/

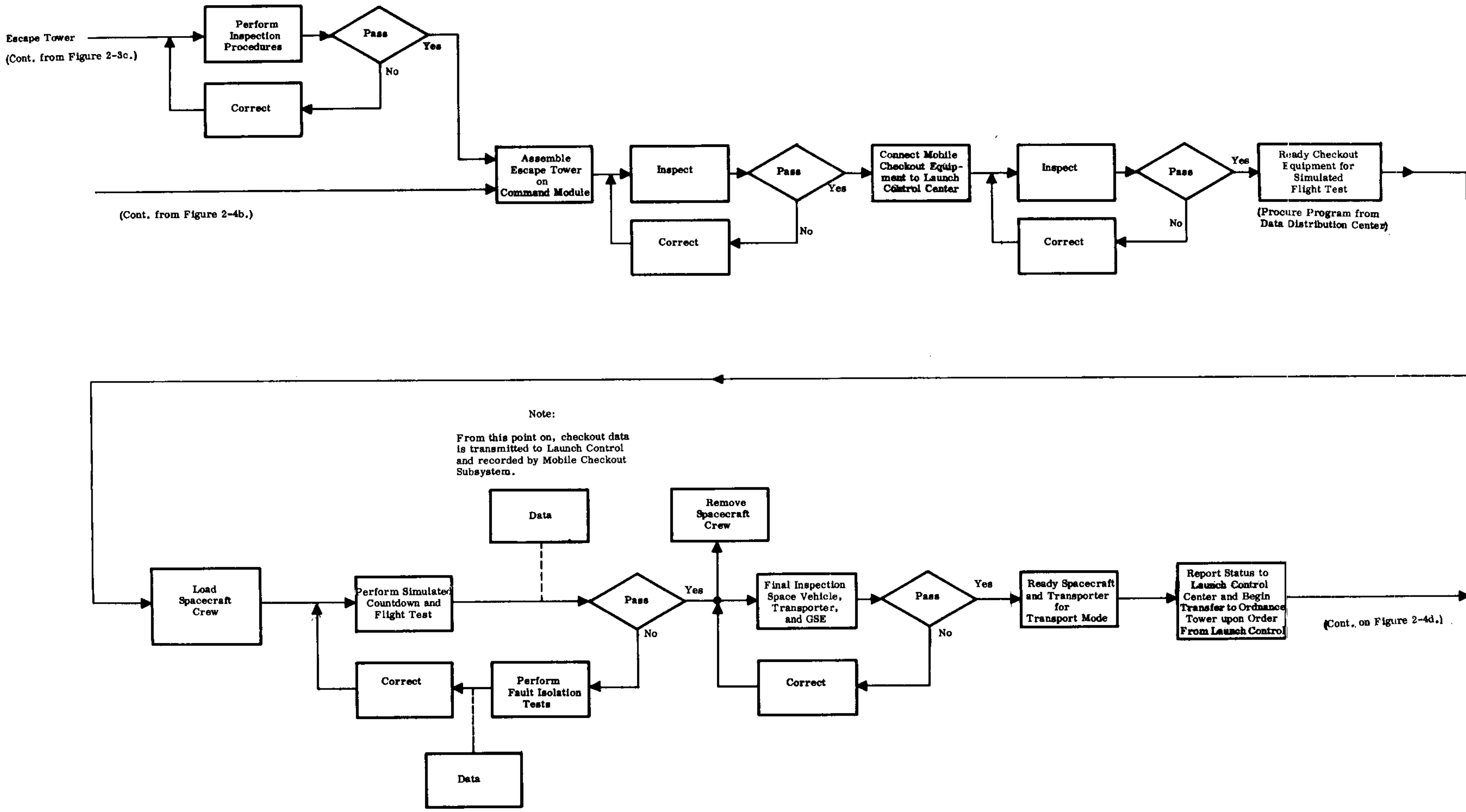


Figure 2-4. Vehicle Assembly Checkout Logic Block Diagram

c. Space Vehicle Assembly - Escape Tower Assembly to Space Vehicle Departure from Vertical Assembly Building

#1

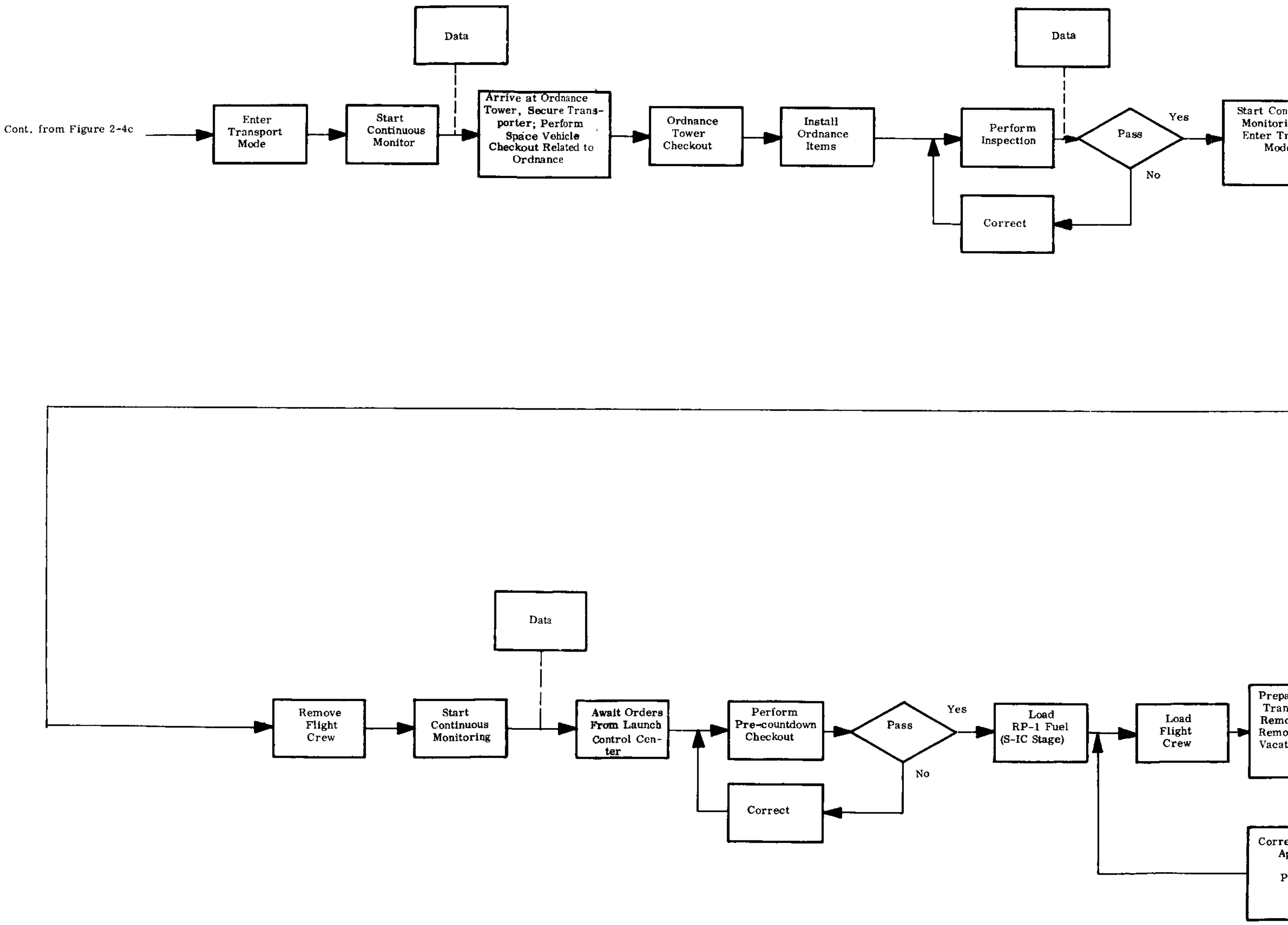
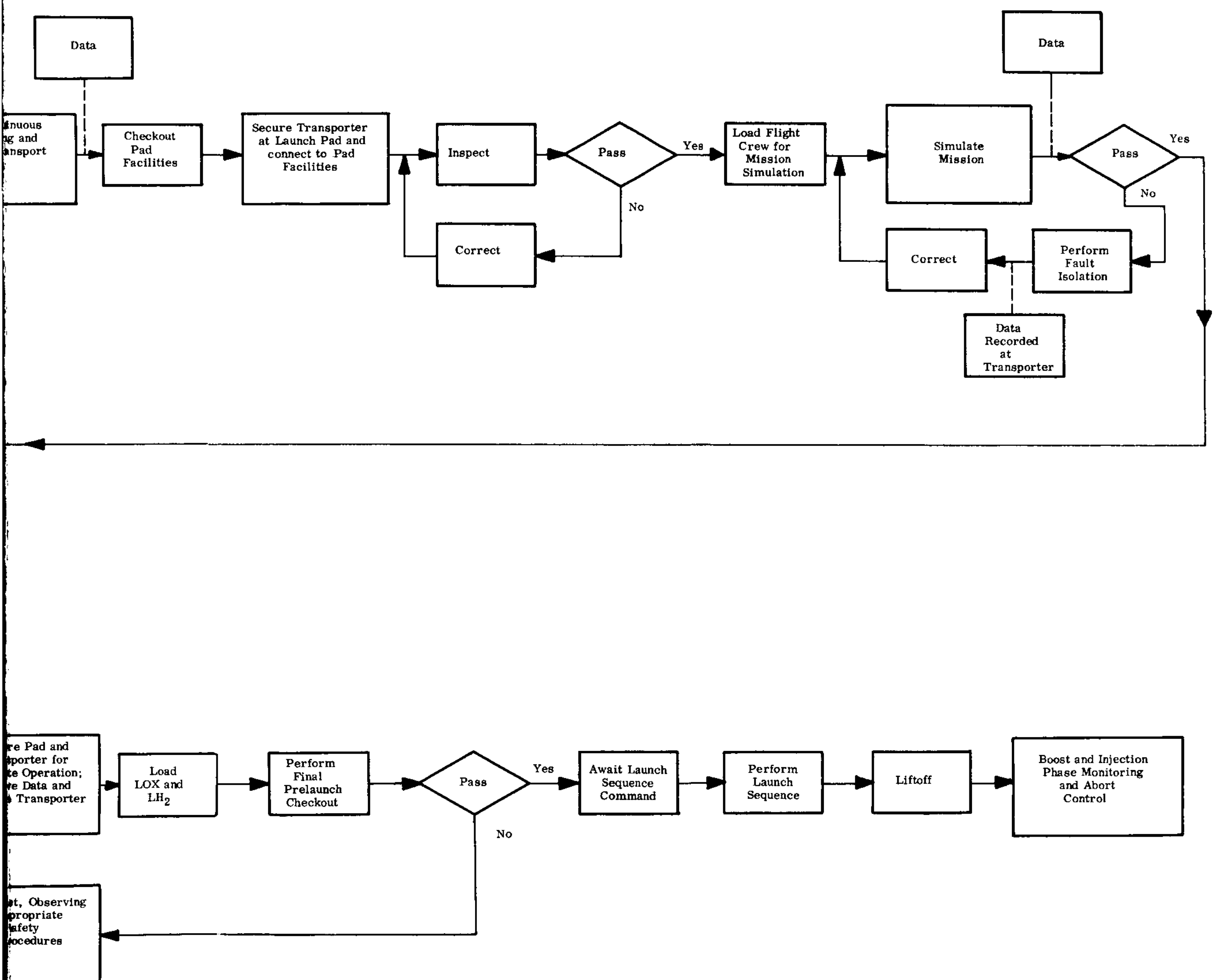


Figure 2-4. Vehicle Assembly Checkout Logic Block Diagram

d. Space Vehicle - Departure from Vertical Assembly Building Through Launch

#2


Data
inuous
ng and
ansport
Checkout Pad Facilities
Secure Transporter at Launch Pad and connect to Pad Facilities
Inspect
Pass
Yes
No
Correct
Load Flight Crew for Mission Simulation
Simulate Mission
Data
Pass
Yes
No
Perform Fault Isolation
Correct
Data Recorded at Transporter
re Pad and
porter for
te Operation;
ve Data and
Transporter
Load LOX and LH_2
Perform Final Prelaunch Checkout
Pass
Yes
No
Await Launch Sequence Command
Perform Launch Sequence
Liftoff
Boost and Injection Phase Monitoring and Abort Control
t, Observing
propriate
afety
ocedures

2.4 DATA FLOW FOR THE INTEGRATED CHECKOUT SYSTEM

The integrated checkout system data-flow diagram, Figure 2-5, displays the data flow paths required to support the historical data-evaluation function. The primary outputs of the historical data-evaluation function are aids to determine the mission operational capability, and to select (or possibly generate) checkout programs for the vehicle checkout (mobile checkout subsystem and the stationary assembly checkout subsystem).

The operational capability prediction is transmitted to the Launch Control Center and Mission Control Center, where with other inputs (GOSS, etc.), launch-status decisions, and mission-status decisions are made. The mission-status decision may result in a hold because of the addition or modification of space-vehicle equipment, which, in turn, can require a change in the mobile checkout subsystem checkout program. If the programs are changed, the changes are sent to the vehicle checkout system and to the Data Distribution Center, where a complete log and data library is kept. The mobile checkout subsystem portion of the vehicle checkout system utilizes the programs to perform required tests on the space vehicle. Detailed checkout data may be requested by the Launch Control Center, or Checkout Data Evaluation Center via the Launch Control Center, in real time. The Checkout Data Evaluation Center may use this data route to compare displayed data with that obtained from a program in order to check the effectiveness of a program.

The data-evaluation function is performed in accordance with a checkout data-evaluation program which is, in turn, a result of a checkout data-evaluation plan and reliability study. The checkout data-evaluation plan results from space-vehicle configuration studies and test procedures. The space-vehicle preassembly test procedures may require changes resulting from analyses performed during formulation of the checkout data evaluation plan.

A third output from the historical data-evaluation function will be determination of the possible need for space-vehicle configuration changes.

The historical data-evaluation function utilizes, in addition to the data at the Vertical Assembly Building and launch site, all pertinent checkout data from the factory to the Vertical Assembly Building.

The Data Evaluation Center provides checkout routines for the vehicle integrated checkout.

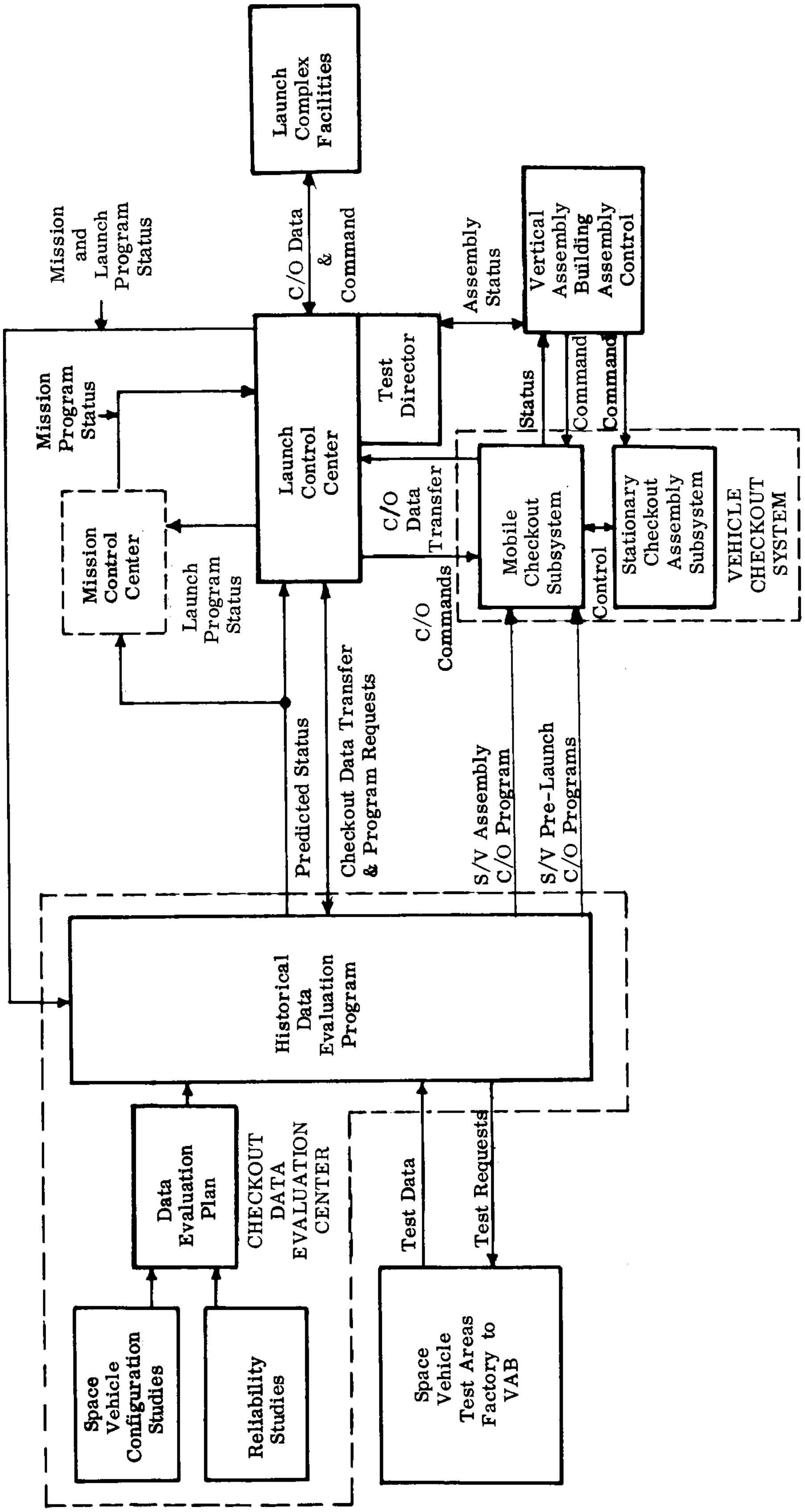


Figure 2-5. Integrated Checkout System Data Flow Diagram

SECTION 3
VEHICLE CHECKOUT SYSTEM

3.1 INTRODUCTION

3.1.1 PURPOSE

The purpose of this section is to discuss the vehicle checkout equipment used in the prelaunch testing and preparation of the space vehicle.

3.1.2 SCOPE

This section considers the equipment needed to test and prepare the space vehicle for launch, from the time of assembly in the Vertical Assembly Building to lift-off. Specifically, the following subjects are discussed:

- The mobile checkout subsystem (the equipment physically located on the transporter and moved to the launch pad along with the space vehicle).
- The stationary assembly checkout subsystem (the equipment located in the Vertical Assembly Building which is required in the assembly of the space vehicle, but not at the launch pad).
- The communication links and information flow during the various prelaunch phases.
- The assumptions on which these concepts are based and the study effort required to verify (or modify) the described approach.

3.1.3 BASIC GUIDELINES

In generating the equipment concept described in this section, certain basic guidelines were followed; the following paragraphs briefly state these "ground rules."

- The purpose of the entire checkout complex is to provide qualified personnel with the information required to make launch decisions.
- A fully automated checkout system is neither possible nor desirable; the man-machine relationship must be optimized.

- At least in the initial stages of the program, the checkout equipment should provide for complete manual "take-over."
- Critical test equipment should be "married" to the prime equipment as early in the test program as possible.
- The part of the test equipment which interfaces directly with the prime equipment should, in general, be designed and manufactured by the prime equipment contractor.
- In general, responsibility for checkout equipment should be along prime contractor lines, that is, Stage I checkout should be the primary responsibility of the Stage I contractor.
- The entire checkout complex must be closely integrated to provide the Launch Control Center with the necessary "real time" information.

3.1.4 SUMMARY OF APPROACH

The following paragraphs briefly outline a "conceptual model" of the mobile checkout and stationary assembly checkout subsystems.* Figure 3-1 is a simplified block diagram which illustrates the concept; a detailed discussion and diagram is contained in paragraph 3.2.

The checkout subsystems are comprised of the following three major elements.

- Adapter complexes
- Adapter controllers
- Transporter-computers

An adapter complex is associated with each space vehicle stage (unit or module); it provides the stimuli, switching test point selection and conversion circuitry (all test results are converted to a digital format) necessary to test the equipment located in the associated stage.

An adapter controller is associated with each adapter complex; it provides programming and display and contains "routines" for all the tests which the associated adapter complex can perform. These routines may be selected manually or by the transporter-computer.

---

* The "conceptual model" is not proposed as a final configuration, but rather as a vehicle for discussion and modification as more detailed information is made available.

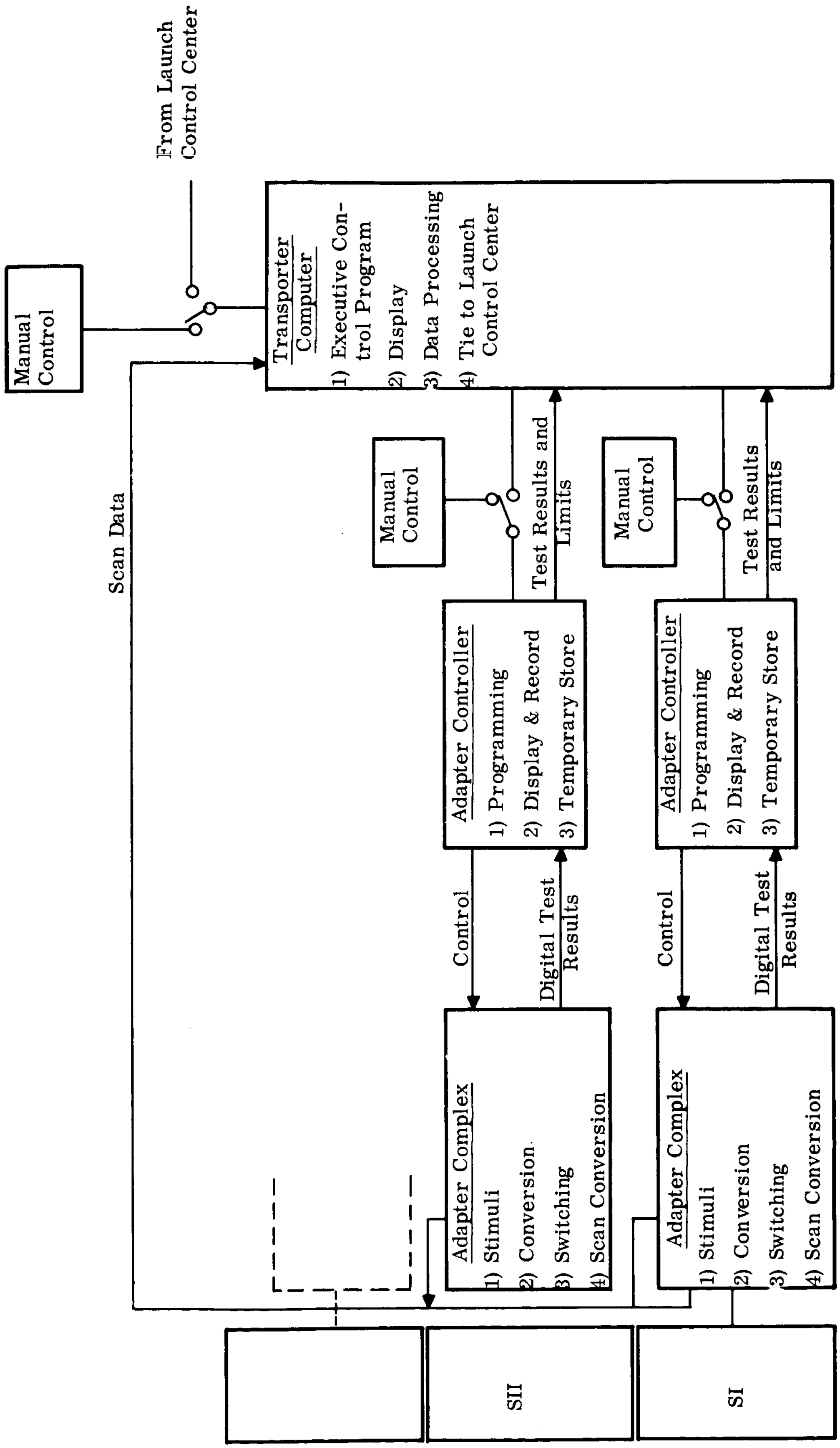


Figure 3-1. Simplified Block Diagram of Checkout Concept

The transporter-computer is located on the transporter-launcher and may be used to control the adapter controllers in the mobile checkout subsystem or in the stationary assembly checkout subsystem, or in both simultaneously, when in the Vertical Assembly Building. This computer provides executive program control (selects the routines which the adapter complexes are to perform) and data processing (processes test results). The transporter computer may be either manually controlled or controlled by the computer in the Launch Control Center.

In addition to these three major elements, the mobile checkout subsystem contains a "continuous monitor" mechanism. This device essentially operates in conjunction with the adapter complexes to continuously monitor key points and/or hazard points in the space vehicle and test equipment.

3.1.5 SIGNIFICANT ASPECTS OF THIS APPROACH

The approach outlined in this section provides:

- A clear-cut definition of responsibilities by specifying checkout equipment along prime equipment contract lines.
- Elimination of a difficult "interface specification" problem by permitting the test equipment which interfaces directly with the prime equipment to be designed by the appropriate prime equipment contractor.
- Opportunity to standardize on equipment and techniques whenever reasonable.
- Opportunity for growth in an integrated and orderly manner by "pyramiding" the programming and data processing.
- A checkout system which is well integrated within itself and well integrated with the over-all data plan.
- A checkout system which is extremely flexible in its adaption to "manual or automatic," "stage or over-all system" and "maintenance or operational" testing.

3.2 CONCEPTUAL MODEL OF VEHICLE CHECKOUT SYSTEM

The following paragraphs consider the mobile checkout subsystem, the stationary assembly checkout subsystem, the communications and information flow network, and the checkout data distribution center. The proposed configuration provides for a combination of adapter complexes, adapter controllers, parallel test point scanners, and general process computers which may be used either as a fully integrated automatic checkout system for the entire space vehicle or as an automatic (or manual) stage/subsystem checkout device. Flexibility and the capability of manual or integrated automatic operation on both the stage or over-all system level are key features of this approach.

The mobile checkout subsystem is oriented toward "operational type tests" and is that portion to the checkout system which accompanies the space vehicle to the launch pad. The adapter complex in the mobile checkout subsystem is essentially a "monitoring" or measuring type device.

The stationary assembly checkout subsystem is essentially oriented toward "maintenance/calibration type tests" and is that portion of the checkout system which remains in the Vertical Assembly Building. The adapter complex in the stationary assembly checkout subsystem is an "in-line" or "stage-simulation" type device in that it is capable of simulating the inputs and loading of "missing" stages during the assembly procedure.

Both checkout subsystems compliment each other during the space vehicle assembly phase; they could also be used with an appropriately programmed adapter controller in the preassembly phase.

3.2.1 MOBILE CHECKOUT SUBSYSTEM

Figure 3-2 is a functional block diagram of the vehicle checkout equipment; the following paragraphs reference the blocks in this diagram.

3.2.1.1 Adapter Complex

An adapter complex is associated with each stage (module or unit) of the space vehicle; it is physically located near its associated stage and converts (if necessary) all test results to a digital format for transmission back to the adapter controller in the transporter control room. In order to minimize lead length for analog signals (both stimuli and test results), the adapter complex is located on the service tower. For this reason, the equipment in an adapter complex will be kept to a minimum; test results which are already in a digital format (and for which cable loading is not a problem) will be sent through adapter switching directly to buffer storage in the Mobile Checkout and Control Room.

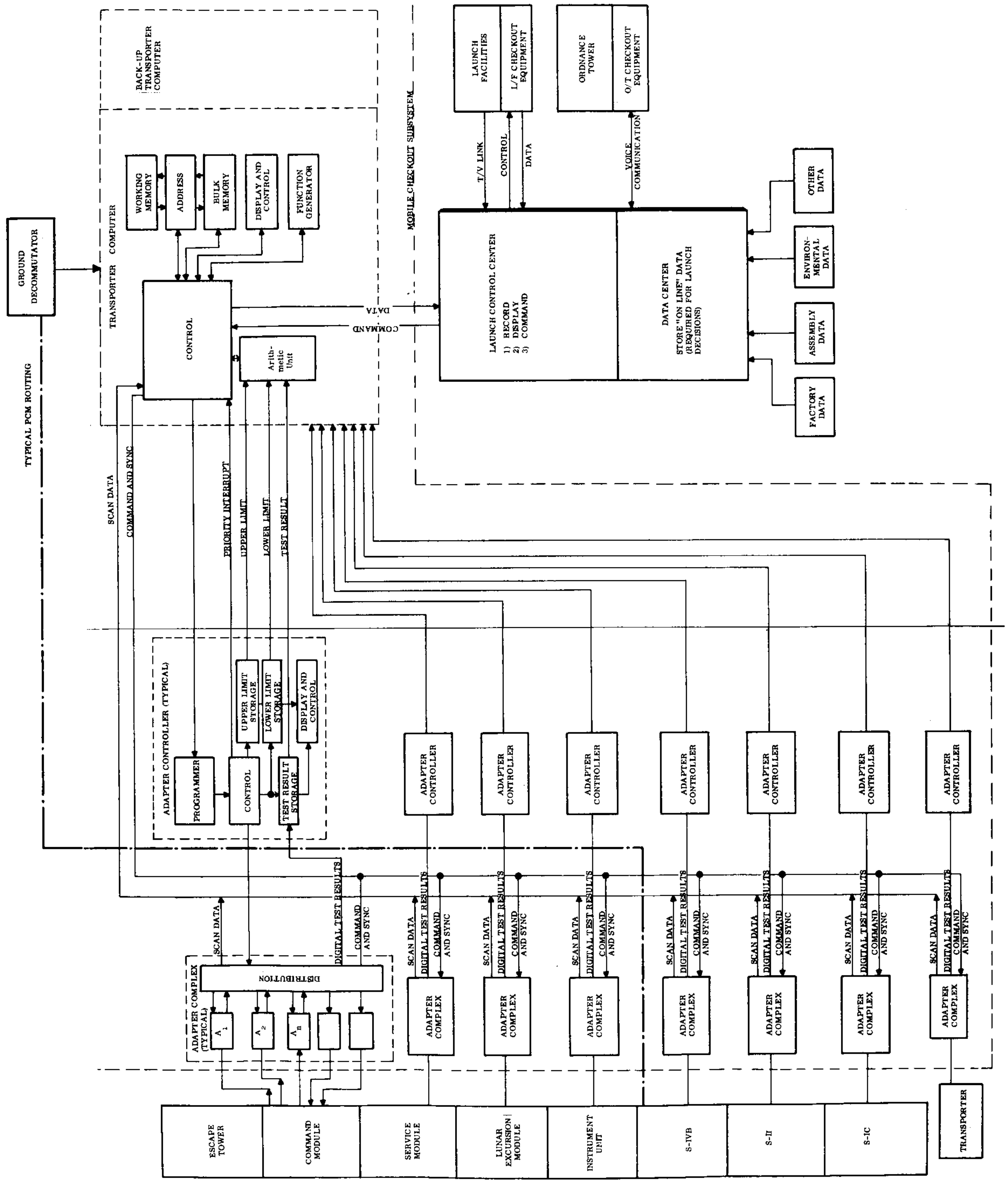


Figure 3-2. Functional Block Diagram of Vehicle Checkout System, Launch Pad Relationships

Measurements in a PCM format would fall into this category; information would be sent via coax directly to the control room where the required decoding and storage would be provided to allow direct computer evaluation (as shown in the dotted portion of Figure 3-2).

An adapter complex will be composed of individual "A" boxes, which contain the necessary stimuli, load simulation, buffering, and/or conversion circuitry associated with specific subsystems within the stage.

A distribution/switching mechanism selects and controls the "A" boxes and the test point to be monitored for a given test. Several examples of adapter complex implementation are presented under "Test Requirements and Implementation Techniques" (3.4).

The adapter complex concept is proposed because:

- Test results are transformed into a digital format as quickly as possible, thus avoiding further loss in accuracy.
- The amount of test equipment which must be located close to the space vehicle is minimized.
- The "A" boxes may be designed and manufactured by the manufacturer of the associated prime equipment or furnished from a stock of standard "A" boxes used in all adapter complexes.
- The "A" boxes may be "married" to the prime equipment early in the over-all testing sequence.

3.2.1.2 Adapter Controller

An adapter controller is associated with each adapter complex; it provides the programming and control for all of the test routines which the associated adapter complex is capable of performing, together with the upper and lower limits for the parameter being evaluated by that routine.

Functionally, the adapter controller would receive a command from the transporter-computer (or from manual instructions) to perform certain routines. The controller would then proceed to set up the appropriate configuration of "A" boxes, load the limit storage registers with the appropriate values, and, when the test result is accumulated in the test result storage register, provide a priority interrupt signal to the computer. The transporter-computer would then accept and process the test result and limits according to an assigned priority.

The adapter controllers (one for each adapter complex - hence, one for each space-vehicle stage) will be physically located in the Mobile Checkout and Control Room; each mounted with a manual control and display console, as shown in Figure 3-3. This control and display panel will provide for manual selection of routines, display of test results, limits, etc., and recording of appropriate data. The test routines will be coded according to the prime equipment which they exercise; the "on time" for critical prime equipment will be accumulated and displayed on this console.

The adapter controller concept is proposed because of the following considerations.

- Programming is simplified because each adapter controller contains only the routines necessary to operate the associated adapter complex. A change in program or in limits can be accomplished at a "low level" and need not effect the entire checkout computer complex.
- The system is easily adaptable to manual control. The routines may be selected manually and the test results visually evaluated.
- Because of its susceptibility to manual operation, an adapter complex and controller may be used at various test locations prior to incorporation into the transporter, and independent of the transporter-computer.
- The adapter controller acts as a "speed buffer" between the high-speed computer and (in many cases) relatively slow reacting adapter and prime equipment circuitry.

3.2.1.3 Transporter-Computer

The transporter-computer will provide the executive control program for the mobile checkout subsystem by selecting the routines which the various adapter controllers are to perform. The transporter-computer will command a given controller to perform certain routines, assign a priority to the test results, and then proceed to address other controllers. When the test result is available, a priority interrupt signal is sent to the computer; on the basis of this assigned priority, the computer accepts the digital test result and limits, processes this data and returns the appropriate information to the Launch Control Center and to adapter controller display.

In order to perform over-all systems tests, i.e., stimulate a circuit in one stage and evaluate the response in another stage, it is sometimes necessary to synchronize the operation of the adapter complexes. The "command and synch" line from the

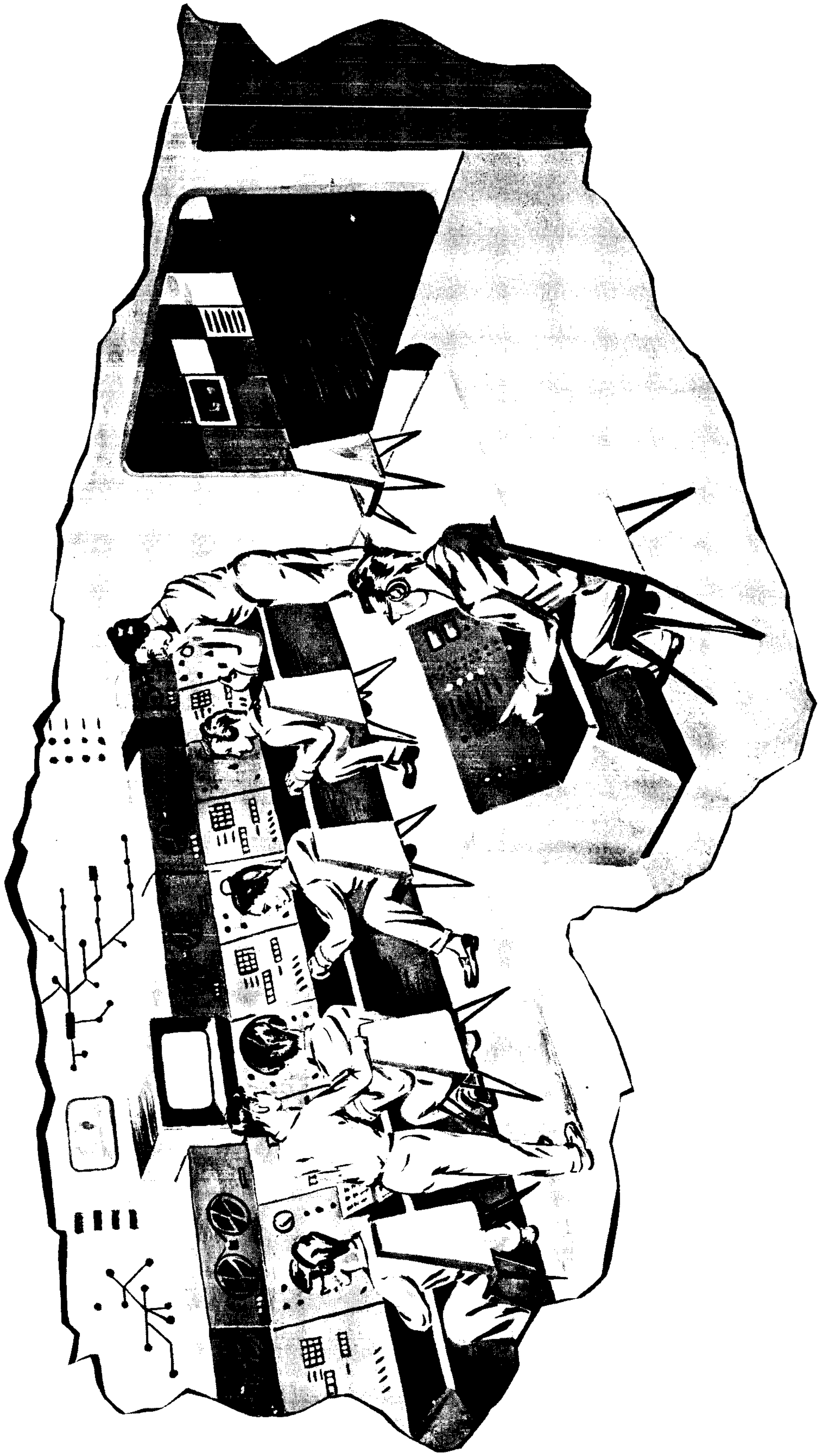


Figure 3-3. Artist's Concept of Mobile Checkout Control Room

transporter-computer will permit routines to be started simultaneously in all adapters (the routines having been previously set up sequentially by computer command) and synchronized throughout the required tests.

Normally, at the launch pad, the transporter-computer will be integrated into the over-all launch complex by the Launch Control Center, however, the mobile checkout subsystem is an integral system capable of independent operation; manual control of the computer and appropriate displays are provided in the mobile checkout control room (see Figure 3-3) for this mode of operation.

Figure 3-2 indicates the presence of a "back-up" computer on the transporter. The primary purpose of this second computer is to insure against a breakdown of the test equipment during the final critical stages of the countdown; control of the adapter controllers may be switched from one computer to the other by the Launch Control Center.

Several other uses for this computer are presently under consideration:

- It could be used as an integrated part of the self-test capability of the Vehicle Checkout System.
- When troubleshooting or fault isolation tests are being performed on, say, the spacecraft using the manual-control mode of the computer, the second computer could be used to continue automatic (or manual) testing of the launch vehicle. Hence, the manual operations, discussions, and decisions would not "tie up" the entire checkout system.
- The second computer could be integrated into the "continuous monitor" system discussed in the following section.

3.2.1.4 Continuous Monitor

In addition to the programmed routines, certain parameters within the space vehicle, which constitute a hazard if out of tolerance, and certain key points within the test equipment will be continuously monitored. The mechanization of this concept is presently being studied; the proposed configuration provides for the adapter complexes to continuously scan these key points and provide a no-go indication to the transporter-computer on a priority interrupt basis. The computer would then command a series of "investigation" routines via the adapter complex and controllers and provide the appropriate information to the Mobile Checkout Control Room and Launch Control Center. In the event of a hazardous condition, the computer would react to eliminate the condition, if possible.

3.2.1.5 After-Ignition Monitoring Equipment

Until a more complete evaluation of the launcher environment is made, it is envisioned that at least the adapter complexes are "pulled away" just prior to launch and that only the minimum amount of test equipment will remain in the area of extreme environment; this will be hardened or expendable.

3.2.2 STATIONARY ASSEMBLY CHECKOUT SUBSYSTEM

The stationary assembly checkout subsystem consists of that portion of the checkout system which is required in assembling the space vehicle in the Vertical Assembly Building, but is not required for operational tests at the launch pad.

The concept of a configuration of adapter complexes, adapter controllers, and a computer discussed in the previous section applies also to the stationary assembly checkout subsystem. The adapter complexes provide the test and maintenance equipment necessary to check out the space vehicle stage by stage during the assembly process; as each stage (unit or module) is attached, the appropriate adapter complex will substitute for the missing stages (units or modules). The adapter controllers and the display and control units are identical to those used in the mobile checkout subsystem.

Figure 3-4 illustrates the various facilities associated with the stationary assembly checkout subsystem; the following paragraphs consider the significant aspects of this diagram.

The stationary assembly checkout subsystem adapter complexes provide four major functions in the Vertical Assembly Building, as shown in Figure 3-5:

- Stage simulation
- Stage substitution
- Calibration, maintenance, and fault-isolation testing
- Tie-in to an adapter controller semi-automated testing

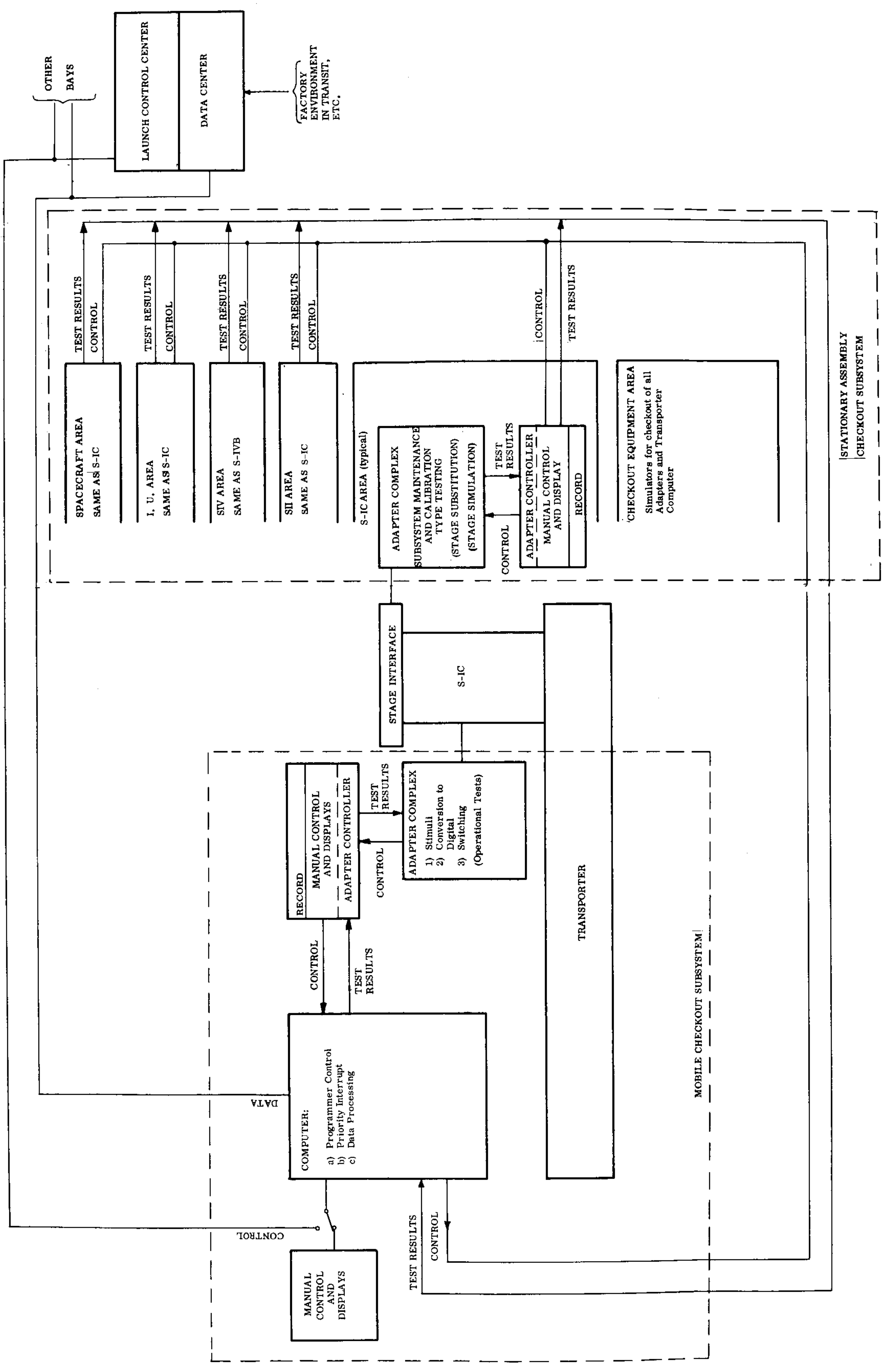


Figure 3-4. Functional Block Diagram of Vehicle Checkout System, Vertical Assembly Building Relationships

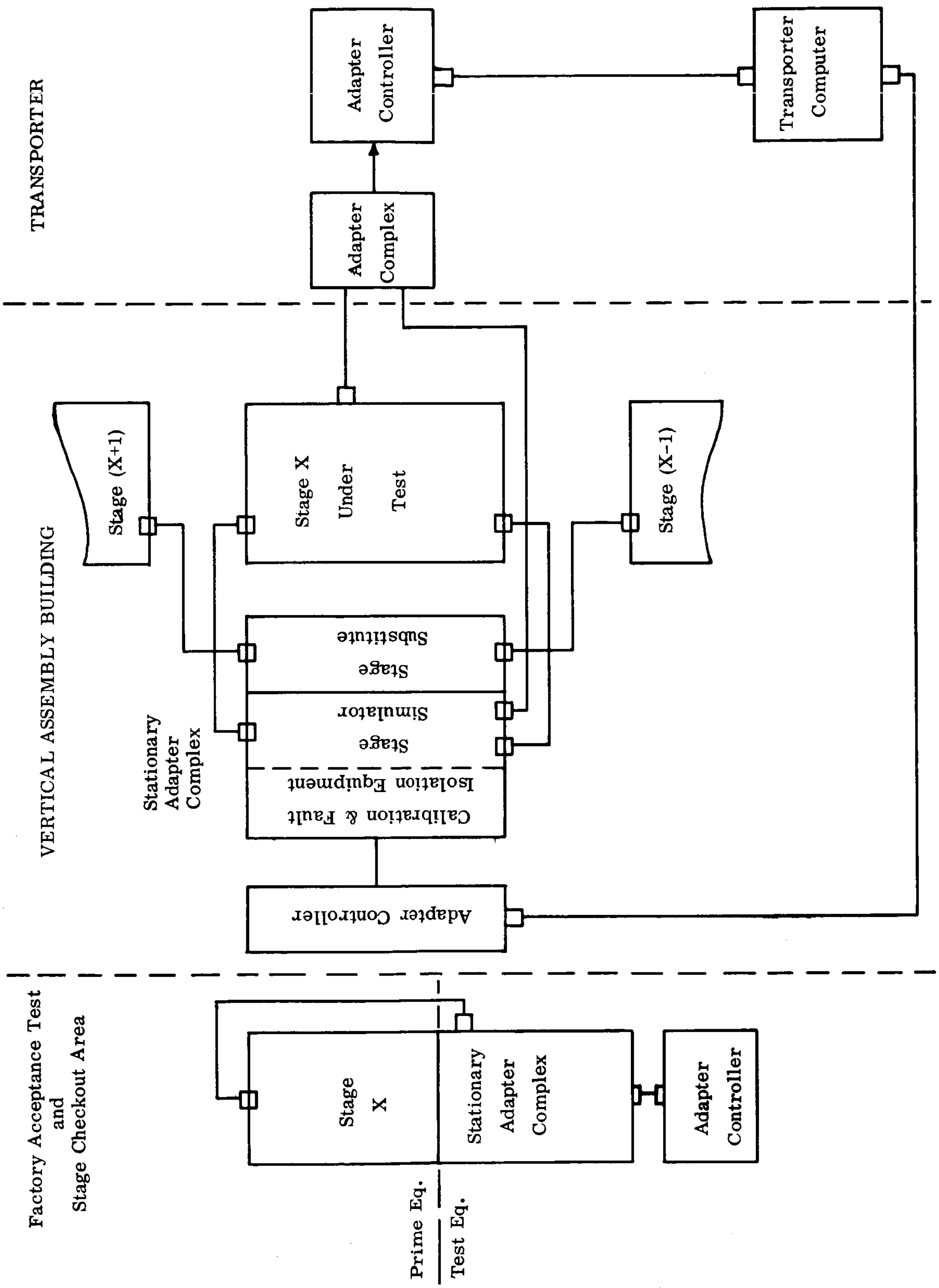


Figure 3-5. Stationary Adapter Complex

3.2.2.1 Stage Simulation

Stage simulation will provide an operating environment for a stage under test. This environment will duplicate the inputs, loads, etc., normally seen by the stage when operating in the assembled vehicle.

3.2.2.2 Stage Substitution

Stage substitution capability is provided to enable vehicle tests to be conducted with one or more stages removed (electrically) for investigation or maintenance. The stage substitution should contain only those functions in which there is interstage dependency.

3.2.2.3 Calibration, Maintenance, and Fault Isolation

The adapter complex for each stage will provide the equipment required to make calibration and alignment adjustments in the subsystems and to the parts of over-all systems (such as flight control) within the stage. In addition, the special equipment required to perform maintenance functions, such as pressurization and leak detection tests, will be included with either automatic or manual control as required by the specific function. During fault-isolation testing, the stationary adapter complex will generate stimuli and provide loads necessary to exercise subsystems and components within the stage.

3.2.2.4 Adapter Controller Tie-In

An adapter controller performs the required display, control, and switching. Modes may be selected for manual, semiautomatic, or full-automatic operation. Provisions are also included for tie-in to the over-all Vertical Assembly Building data complex.

3.2.2.5 General Requirements for Stationary Adapter Complexes

The requirements for the adapter complexes for the various space-vehicle stages must be considered for the three basic operational locations, i.e., factory, Vertical Assembly Building, and transporter-launcher. The utilization of these stage adapters must be planned to provide useful test data for the Integrated Data Plan.

At the Vertical Assembly Building, stages are checked individually using qualification equipment. As the vehicle buildup progresses, major subsystem and systems tests are performed. The primary checkout function of the mobile checkout subsystem will be the monitoring of the major system functions of the assembled space vehicle, and only if malfunctions are encountered will subsystem and component tests be made.

If faults are detected during the stage checkout, the adapter complex, through utilization of subprogram routines, will effect fault isolation to the replaceable-unit level. During test sequences on individual stages, the transporter equipment may also be tied into stage monitoring points via the umbilical plug for test-result comparison.

As in the mobile checkout subsystem, an adapter controller is associated with each adapter complex and contains the program for all routines which the adapter complex is capable of performing; these routines may be selected manually or automatically via the transporter-computer. The transporter-computer, in turn, can be controlled manually or automatically via the Launch Control Center.

Both the mobile checkout subsystem and the stationary assembly checkout subsystem can be controlled by the transporter-computer, hence, providing an integrated checkout system. Both checkout subsystems will be used in checking each stage before the next stage is added. After the space vehicle is completely assembled and the results of all tests are found acceptable, "responsibility" for checkout is transferred to the mobile checkout subsystem, a complete operational test is made under the direction of the Launch Control Center, and (if results are positive) the space vehicle is moved out of the Vertical Assembly Building.

The value of this concept lies in its versatility. Tests may be performed manually or automatically, integrated via the computer or separately and in parallel. The testing may be accomplished manually and gradually transferred to automatic control, hence permitting verification of programs and the generation of operator confidence.

The "checkout equipment area" provides the capability of testing and calibrating the various adapter complexes, controllers, etc. Simulators of the equipment to be tested would be provided to permit rapid confidence and maintenance tests to be made on the various adapter complexes.

3.2.3 INFORMATION FLOW AND COMMUNICATIONS

During the period beginning with space-vehicle assembly in the Vertical Assembly Building and ending with lift-off from the launch pad, there will be considerable information flow between the several facilities comprising the Integrated Checkout System. These information flow channels appear in Figure 2-1 (Integrated Checkout System Functional Block Diagram) and are summarized in Table 3-1. It should be noted that:

- Information is of several types (for example, voice or digital data).
- Several transmission modes are involved (for example, microwave link or hand carried).
- Real-time and nonreal-time communication is involved.

The purpose of all such information flow is to enable the Launch Control Center to make the most informed decision possible concerning vehicle launch.

Table 3-2 details each channel of information flow to indicate the many kinds of commands, requests, and reports carried in each channel during the various phases of the launch cycle. It serves to summarize functions performed by the Integrated Checkout System, and to identify where in the system the functions are performed.

Table 3-2 may also be used as a basis for specifying the configuration of the communication links. For example, from the chart, the quantity of data, its importance, and the urgency of its transmission can be estimated for each information flow channel. Certain technical and operational factors also enter into the decision on the communication-link configuration. These factors, and the recommended configurations, are summarized in Table 3-3.

3.2.4 CHECKOUT DATA DISTRIBUTION CENTER

The Checkout Data Distribution Center, located within the launch complex, will contain all test programs pertinent to a given equipment configuration. Further, this library will assemble and store all test results (raw and processed) from checkout of the space vehicle(s) assigned to that equipment configuration. The test programs are prepared at the Checkout Data Evaluation Center, and are physically transferred to the Checkout Data Distribution Center. When an equipment configuration is defined, applicable test programs will be drawn, physically transferred to the mobile checkout subsystem,

Table 3-1

Integrated Checkout Information Flow Channels for Period from Space Vehicle Assembly in Vertical Assembly Building to Launch

From / To	Launch Control Center	Mobile Checkout Subsystem	Stationary Assembly Checkout Subsystem	Checkout Data Distribution Center	Checkout Data Evaluation Center	Launch-Pad Facility	Space Vehicle	Mission Control Center	Ordnance Tower
Launch Control Center		1-B		2-B	3-B	4-B	5-B	11-B	12-B
Mobile Checkout Subsystem	1-A		9-B	8-B	13	6	7-B		
Stationary Assembly Checkout System		9-A							
Checkout Data Distribution Center	2-A	8-A			10-B		12		
Checkout Data Evaluation Center	3-A			10-A					
Launch-Pad Facility	4-A								
Space Vehicle	5-A	7-A							
Mission Control Center	11-A								
Ordnance Tower	12-A								

Note: Numbers in squares reference discussion of the communication link in Table 3-2.

Table 3-2

Integrated Checkout Information Flow for Phases in Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch

Information Flow Channel	Launch Cycle Phase			
	Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad - Launch Sequence
1A. Launch Control Center to Mobile Checkout Subsystem	(1) Administrative communication (2) Status requests (3) Control of final pretransit operational tests	(1) Proceed, stop, or return commands to transport (2) Administrative communication (3) Status requests	(1) Requests for specific checkout tests (2) Requests for specific monitor (3) Checkout program selection command (4) Checkout program modification (5) Administrative communication	(1) Request for specific monitor (2) Launch sequence (3) Range time
1B. Mobile Checkout Subsystem to Launch Control Center	(1) Status reports (2) Administrative communication (3) Test results et. al., of final pretransit operational tests	(1) Critical space vehicle subsystem status reports (2) Transport vehicle status reports (3) Administrative communication	(1) Normal test results (2) Over-all status of space vehicle checkout (3) Specific test results or raw test data as requested (4) Administrative communication (5) Television monitors	(1) Normal test results (monitor only no stimuli) (2) Television monitors (3) Change of a space vehicle subsystem status to an unsafe condition (hazard reporting)

Table 3-2

Integrated Checkout Information Flow for Phases in Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase			
	Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad - Launch Sequence
2A. Launch Control Center to Checkout Data Distribution Center	(1) Administrative communication	(1) Request for specific raw test data (on a critical space vehicle subsystem) (2) Administrative communication	(1) Request for specific raw test data (2) Administrative communication	
2B. Checkout Data Distribution Center to Launch Control Center	(1) Administrative communication	(1) Specific raw test data as requested (2) Administrative communication	(1) Specific raw test data as requested (2) Administrative communication	
3A. Launch Control Center to Checkout Data Evaluation Center	(1) Administrative communication	(1) Request for effect on launch plan and mission successes of possible overstressing of critical space vehicle subsystem (2) Administrative communication	(1) "Change checkout program and forward to Mobile Checkout Subsystem" (2) Request for effect on system of specific space vehicle subsystem performance (3) Administrative communication	

Table 3-2

Integrated Checkout Information Flow for Phases in Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase: Space Vehicle Assembly in Vertical Assembly Building	Launch Cycle Phase: Space Vehicle in Transit to Ordnance Tower or Launch Pad	Launch Cycle Phase: Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Launch Cycle Phase: Space Vehicle at Launch Pad - Launch Sequence
3B. Checkout Data Evaluation Center to Launch Control Center	(1) Recommended change in checkout program	(1) Results of requested analysis (3A)	(1) Results of requested analysis (3A) (2) Recommended change in checkout program	
4A. Launch Control Center to Launch-Pad Facility	(1) Checkout commands to insure launch-pad facility ready to receive space vehicle		(1) Checkout commands to insure space vehicle and launch-pad facility are properly tied together and ready for launch phase	(1) Commands pertaining to fueling, etc.
4B. Launch-Pad Facility to Launch Control Center	(1) Checkout status	(1) Checkout status	(1) Checkout status (2) Television	(1) Fueling status; thrust build-up (2) Television monitor
5A. Launch Control Center to Space Vehicle			(1) Request for status reports from astronauts	(1) Request for status reports from astronauts

Table 3-2

Integrated Checkout Information Flow for Phases in Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase: Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad-- Launch Sequence
5B. Space Vehicle to Launch Control Center			(1) Status reports from astronauts	(1) Telemetry data (2) Voice link from astronauts
6. Launch-Pad Facility to Mobile Checkout Subsystem				(1) Signals to coordinate fueling and other launch phase events
7A. Mobile Checkout Subsystem to Space Vehicle	(1) Test stimuli and mission simulation signals (2) Voice link to astronauts in command module		(1) Test stimuli and simulation signals (2) Voice link to astronauts in command module	
7B. Space Vehicle to Mobile Checkout Subsystem	(1) Test response and monitor data (2) Voice link from astronauts in command module	(1) Critical subsystem monitor data	(1) Test response and monitor data (2) Voice link from astronauts in command module	(1) Space vehicle subsystem monitor data (2) Voice link from astronauts

Table 3-2

Integrated Checkout Information Flow for Phases to Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase			
	Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad - Launch Sequence
8A. Mobile Checkout Subsystem to Checkout Data Distribution Center	(1) Test results		(1) Processed test data (2) Raw test data (physically carried from mobile checkout subsystem prior to launch phase)	(1) Monitor data from space vehicle subsystems
8B. Checkout Data Distribution Center to Mobile Checkout Subsystem	(1) Checkout programs			
9A. Mobile Checkout Subsystem to Stationary Assembly Checkout Subsystem	(1) Test commands			
9B. Stationary Assembly Checkout Subsystem to Mobile Checkout Subsystem	(1) Test responses			

Table 3-2

Integrated Checkout Information Flow for Phases to Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase			
	Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad - Launch Sequence
10A. Checkout Data Distribution Center to Checkout Data Evaluation Center	(1) Processed and raw test data	(1) Processed test data (as available)	(1) Processed and raw test data	(1) Space vehicle subsystem monitor data
10B. Checkout Data Evaluation Center to Checkout Data Distribution Center	(1) Checkout programs (2) Request for specific data		(1) Request for specific data	
11A. Launch Control Center to Mission Control Center		(1) Space vehicle checkout status launch cycle commands required for checkout status	(1) Space vehicle checkout status launch cycle commands required for checkout status	(1) Space vehicle checkout status launch cycle commands required for checkout status
11B. Mission Control Center to Launch Control Center				

Table 3-2

Integrated Checkout Information Flow for Phases to Launch Cycle from Space Vehicle Assembly in Vertical Assembly Building to Launch (Cont.)

Information Flow Channel	Launch Cycle Phase			
	Space Vehicle Assembly in Vertical Assembly Building	Space Vehicle in Transit to Ordnance Tower or Launch Pad	Space Vehicle at Launch Pad (or at Ordnance Tower) - Prelaunch Checkout	Space Vehicle at Launch Pad - Launch Sequence
12A. Launch Control Center to Ordnance Tower	(1) Administrative communication	(1) Administrative communication	(1) Commands concerning installation of pyrotechnics in space vehicle	
12B. Ordnance Tower to Launch Control Center	(1) Ordnance tower checkout status (2) Administrative communication	(1) Ordnance tower checkout status (2) Administrative communication	(1) Monitor installation of pyrotechnics (including television) (2) Administrative communication	

	Launch Control Center	Mobile Checkout Subsystem	Stationary Assembly Checkout Subsystem	Checkout Data Distribution Center	Checkout Data Evaluation Center	Launch-Pad Facility	Space Vehicle	Mission Control Center	Ordnance Tower
Launch Control Center		(1) Coaxial cable link (provides different mode of transmission and transmission during RF radiation silence) alternates: LASER communication or second microwave link (2) VHF voice link and low data rate link (3) Possible high-speed microwave link		Hardline voice link	Hardline Voice link	Hardline voice, data, and television monitor link	Via Mobile Checkout Subsystem: (1) Voice link to astronauts (VHF) (2) Vehicle test stimuli and responses, and monitor data (microwave link) Via Ground Operations Support System: (1) VHF voice link to astronauts (2) Vehicle telemetry	Highspeed link - hardline and/or microwave	Hardline voice, data, and television monitor link
Mobile Checkout Subsystem			Hardlines (internal to Vertical Assembly Building)	Physical transport of checkout programs to mobile checkout subsystem and raw test data to checkout data distribution center	Physical transport of program modifications to mobile checkout subsystem	Hardline links	Hardline voice link to astronauts; vehicle test stimuli and responses, and monitor data		Hardline links
Stationary Assembly Checkout Subsystem							Hardline links		
Checkout Data Distribution Center					Physical transport of data to checkout data evaluation center; hardline voice link		Vehicle telemetry data to checkout data distribution center via ground operations support system (also goes to launch control center)		
Checkout Data Evaluation Center									
Launch-Pad Facility							Hardline links		
Space Vehicle									
Mission Control Center									
Ordnance Tower									

Table 3-3

Communications Network for Integrated Checkout System and placed in storage at that location. Test data arrives at the Checkout Data Distribution Center from the mobile checkout subsystem via physical transporting of tapes, cards, etc.; data from the Checkout Data Distribution Center to the Checkout Data Evaluation Center and Launch Control Center is similarly physically transported to those facilities. No real-time link connecting these facilities is envisioned, although hardline voice links and low-data-rate data links will exist.

3.2.5 LAUNCH-PAD FACILITIES AND ORDNANCE TOWER

In addition to the checkout system on the transporter-launcher and in the Vertical Building Building, test/checkout and control equipment is required to service the launch-pad facilities (fueling, etc.) and the ordnance tower. The test equipment in these areas would be capable of independent operation; the launch facilities would be integrated into the over-all launch complex by a command line, a data line, and closed-circuit television lines to the Launch Control Center; the ordnance tower is connected to the Launch Control Center by voice communication, and hardline digital-data links.

The sequence and description of the ordnance functions performed at the ordnance area and the launch pad are defined in succeeding paragraphs and summarized in Figure 3-6. The basic concept involved in defining the sequence and description of functions to be performed, is <u>maximum degree of personnel safety consistent with program requirements</u>.

The preceding statement means that the flow described should be considered as an input to the space-vehicle system design goals. In defining the flow, the following assumptions were made:

- The ordnance devices themselves will have been tested as components, based on the reliability figure assigned to them, and no component testing will be required after they are delivered to the ordnance area.
- The space-vehicle system will be designed to allow installation of all solid explosive devices with the space vehicle completely assembled.
- A complete safety check of the space-vehicle ordnance systems is required whenever the space-vehicle/transporter-launcher configuration is moved from one area to another.

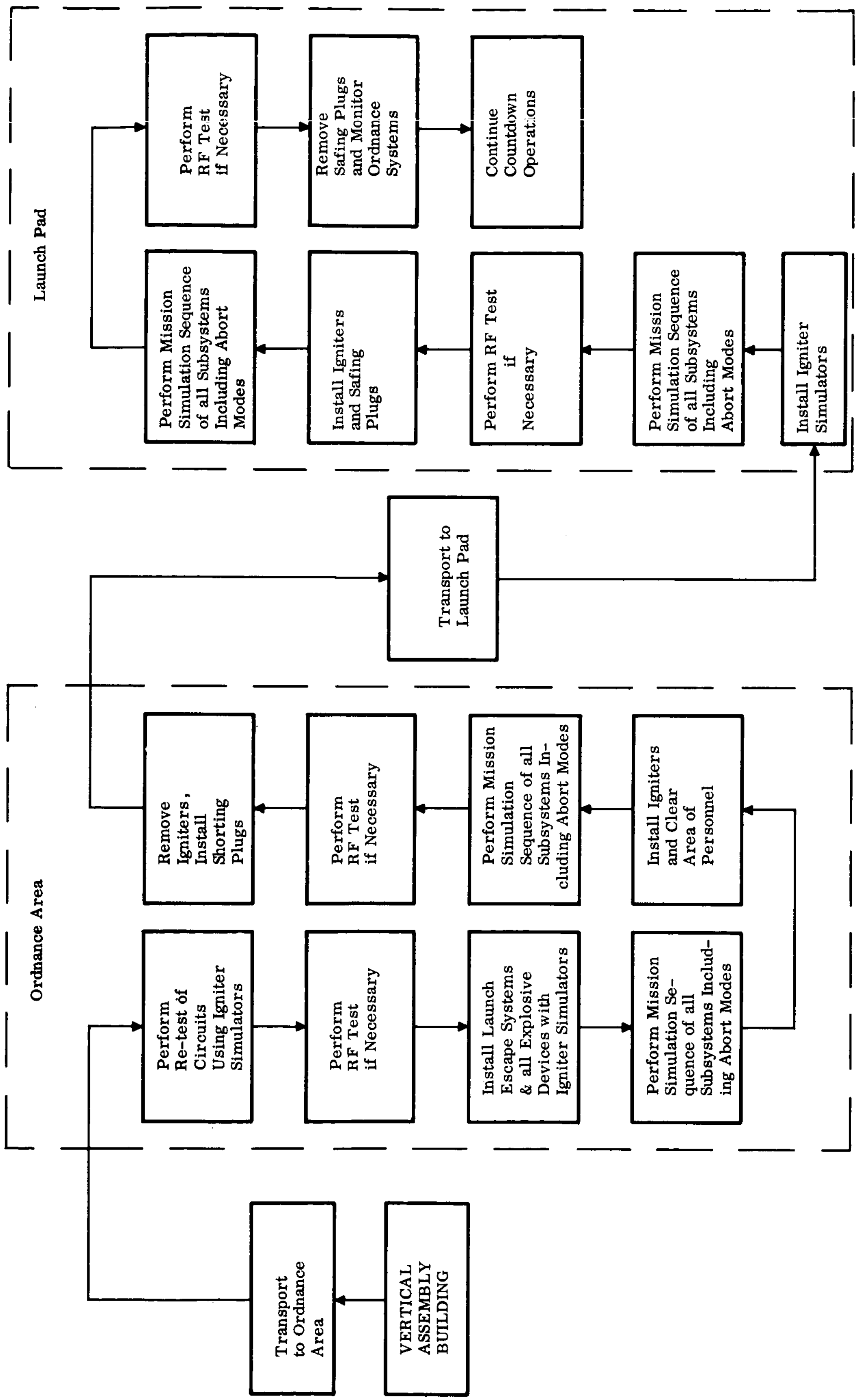


Figure 3-6. Ordnance Operations Flow

- The checkout system carried on the transporter-launcher is adequate to demonstrate complete system integrity.
- The checkout system carried on the transporter-launcher will be designed to perform a completely automatic checkout of the ordnance system when all explosive devices, ignitors, and initiators are installed and armed.

The performance of complete safety checks, at present, includes RF tests to assure that the ordnance systems can safely exist in the expected Cape Canaveral RF environment. However, the necessity for continuation of this requirement is questioned. This is based on the present AMR range safety requirement of 1-watt, 1-amp no-fire specification on all ordnance devices. It is recommended that a detailed analysis of the problem be instituted as early as possible in the program with the specific goal of eliminating RF testing as a requirement for assuring safety of the ordnance systems. The desire for eliminating the RF test on the ordnance systems is due to the time required to perform the test and the difficulty involved in scheduling the test, since range equipment is involved and, hence, scheduling must be consistent with the requirements of other programs.

Following the completion of system checkout in the Vertical Assembly Building, and when information is received on the readiness status of the ordnance area, the space vehicle, carried on the transporter-launcher, will be moved to the ordnance area for installation of all solid pyrotechnics (escape-tower propellants, interstage separation devices, turbine spinners, destruct mechanisms, activation devices, etc.). Separate from these are the ignitors, or squibs, which cause the pyrotechnics to operate. Tests which are necessary to show safe and proper operation of the space-vehicle pyrotechnic circuitry will be performed in detail at the ordnance area, even when redundant to tests that are to be performed at the launch pad. Thus, destructive failures would occur in a comparatively safe area, while the space vehicle, though configured for flight, has no fuel or personnel on board.

During the checkout operations, test data status reports will be transmitted to the Launch Control Center. The sequence of the installation and checkout procedures at the ordnance area will be as follows:

a. Upon arrival at the ordnance area, all circuits whose functions are to initiate pyrotechnic devices will be tested for proper operation by firing a simulator under "worst-case" conditions. Worst-case conditions represent the lowest possible firing voltages using ignitor simulators whose firing characteristics are at the worst-case limit of the design specification for the ignitors.

b. Ignitor simulators will again be installed and all ground and space-vehicle RF systems energized to test that improper ignition by the RF energy does not occur. In this test, "best-case" simulators would be used (those which fire with the least energy).

c. On completion of b. above, all solid pyrotechnics (less ignitors) will be installed. With ignitor simulators installed, an abbreviated mission-profile system checkout will be run to ensure proper system operation. Ignitors will be monitored to insure that no pre-ignition occurs and that actual operation is correctly timed. Tests of all abort modes will be included.

d. Next, the actual flight ignitors will be installed as for flight, and a mission-profile system checkout, which is similar to that in c. (above), performed. This modified checkout will include all subsystem operations except those which would initiate any pyrotechnic device. As a portion of this test, all ground RF systems would be energized. During this test, the area would be cleared of personnel for safety reasons.

e. After completion of the mission-simulation and RF tests, the ignitors and initiators will be removed and replaced by shorting plugs. The space-vehicle/transporter-launcher configuration will then be moved to the launch pad.

After the space vehicle and the transporter-launcher have arrived at the launch pad, tests similar to those which were run at the ordnance area must be performed. These tests are necessary to verify that the movement of the space vehicle and the different environment encountered in the launch area do not cause any malfunctions or changes in operating characteristics. Of particular interest is in the proper and safe operation of the pyrotechnic circuits. The necessary ordnance functions are as follows:

a. Ignitor simulators will be installed and an abbreviated mission-profile system checkout performed. All abort modes will be tested. All pyrotechnic circuits will be continuously monitored. All space-vehicle and ground RF systems will be energized to determine susceptibility to the launch-pad RF environment.

b. The flight ignitors, with safing plugs, will then be installed in all pyrotechnics. A mission-profile system checkout, which does not include pyrotechnic-circuit operation, will then be run to give positive assurance of proper operation. The pyrotechnic circuits will be continuously monitored for detection of any incorrect functioning. RF susceptibility tests, as in a. (above), may be performed if deemed necessary.

c. The safing plugs will then be removed at some point in the countdown and the countdown continued.

3.3 TEST REQUIREMENTS AND IMPLEMENTATION TECHNIQUES

The space-vehicle checkout system interface is defined, for the most part, by the respective functional systems that comprise the space vehicle, the parameters to be measured or excited, the available test access points, and the test techniques employed. In a sense, the very fact that the space vehicle is divided into major functional units (i.e., stages, modules, etc.) also lends a certain reasonableness to a similar functional division of the checkout equipment at the space-vehicle checkout system interface. As outlined earlier in Section 3.2, the major functional division of the checkout systems at the vehicle interface is the adapter complex which, in turn, contains the individual "A" units necessary to provide stimuli, loading, buffering, and conversion circuitry for subsystems within the vehicle stage. For example, the adapter complex for the spacecraft command module would contain "A" units for the guidance and navigation subsystem, the stabilization and control subsystem, the environmental control subsystem, etc. The operation of the "A" units can be coordinated by the adapter controller to test integrated subsystems (for example, the guidance and navigation/stabilization and control combination). The adapter complexes, in turn, can be coordinated by the transporter-computer (via the adapter controllers) to test systems which transcend vehicle stage interfaces, for example, the Flight Control System.

The implementation of the adapter portions of the checkout system will result from studies conducted in conjunction with the associated equipment contractors (via NASA) to determine what parameters should be monitored to obtain a satisfactory indication that the space vehicle is ready for flight.

As an aid in defining what unique functions may be contained in some of the "A" units, the test requirements and possible implementation techniques for representative space-vehicle functions are discussed in the following paragraphs. Some of the concepts apply to the tests performed both during assembly and at the launch pad; others apply only to the assembly phase of the checkout.

3.3.1 FLIGHT-CONTROL TESTS

A control system has the function of stabilizing the vehicle and carrying out the commands of a guidance system or a pilot input. It must shape the response of the vehicle to meet some desired response. Because of these requirements, the transient response of the control system, as well as the steady-state response, are quite important. A control system checkout is incomplete unless both types of responses are checked.

The nature of the control system is such that mechanical motions of sensors are converted to electrical signals and these are "transformed" to new electrical signals through controlling networks. These new control signals are then applied to some form of actuation which again results in mechanical motion. Thus, the checkout of the control system involves electrical and physical quantities, such as volts, amps, degrees, etc.

In addition to these signal quantities, the "support" quantities, such as power-supply voltages and hydraulic-systems pressures, must be checked out.

If the system is redundant or failure correcting, its capabilities in these areas must be checked through simulated failures in the equipment.

In order to complete the checkout of the system's transient and steady-state responses, many forms of tests are applied. These include calibration tests, null tests, step input tests, and frequency response tests. These tests must meet certain system specifications; they must be applied at specific times in the "countdown;" and they should be applied in a certain sequence. Many of these detail items depend on the specific launch vehicle.

The instrumentation unit stage could have been assembled and tested prior to this time; it, or an adapter complex (simulator) of it could then be used to provide the test signals for the S-IC stage control components. This insures compatible operation of the control system before the vehicle is completely assembled.

This will be done for each stage as it is erected and placed on the total assembly.

The tests that are made will include frequency responses, signal-to-noise tests, and over-all gain and linearity checks.

After this type of checking a go, no-go type of test can be provided, using a sensor torque test signal as an input, as described below.

The present state-of-the-art rate gyros and linear accelerometers have built-in test features. In most cases, this is accomplished by a torquing coil which applies a torque on the readout gimbal of the sensor. This torque is opposed by the restraining spring of the gimbal. Thus, for a given torque current, a given signal will be read at the sensor pickoff.

Such a device will provide a convenient point for the checkout system to apply a subsystem test signal. When the control system shown in Figure 3-7 is considered, the application of the gyro test signal should cause some "action" at the actuator. This "action" will depend on the time of test. If the stage has not been connected to the next stage the "action" will be motion of the engine. The electrical feedback sensor can then be used to check the quantities of interest.

After staging, the same tests may again be applied, but possibly over a smaller range of frequencies and amplitudes because of engine gimbal limiting.

Assuming that the engines are free to move, a given sine-wave input can be applied on the torque test input. The actuator follow-up will detect the engine motions. This follow-up signal should have a definite gain and phase relation with respect to the input if the system is operating properly. The use of two or three frequencies will provide a spot check of the system transfer function.

If, staging requires locking on the engine gimbals, the actuator will be unavle to move. However, pressure levels inside the actuator will change; the use of pressure sensors within the actuator will then enable a check of the mode.

The use of two pressure sensors and logic on their output will enable a number of items of the control system to be checked. Figure 3-8 illustrates how the sensors would be used, the following paragraphs discuss this diagram.

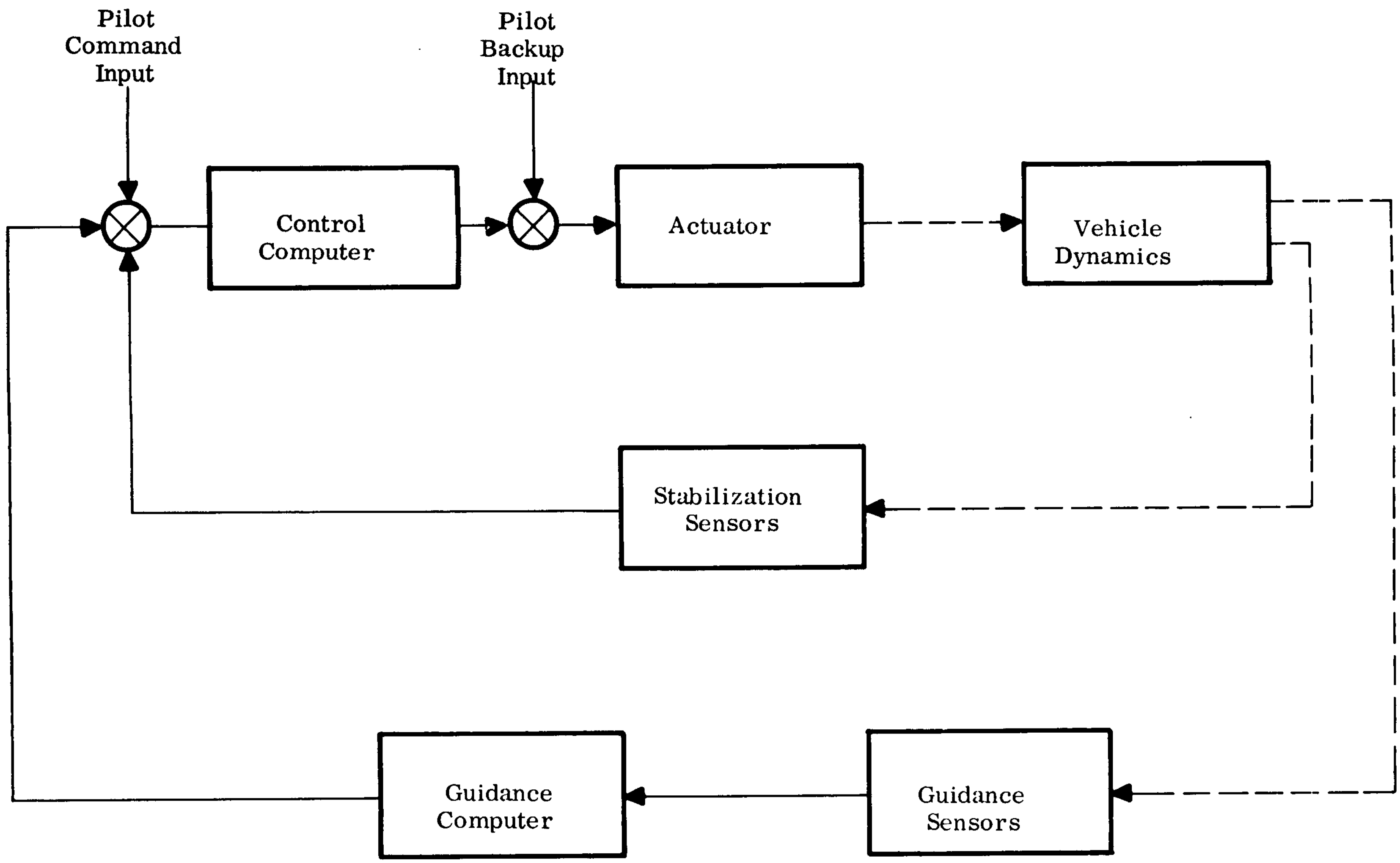


Figure 3-7. Control System Block Diagram

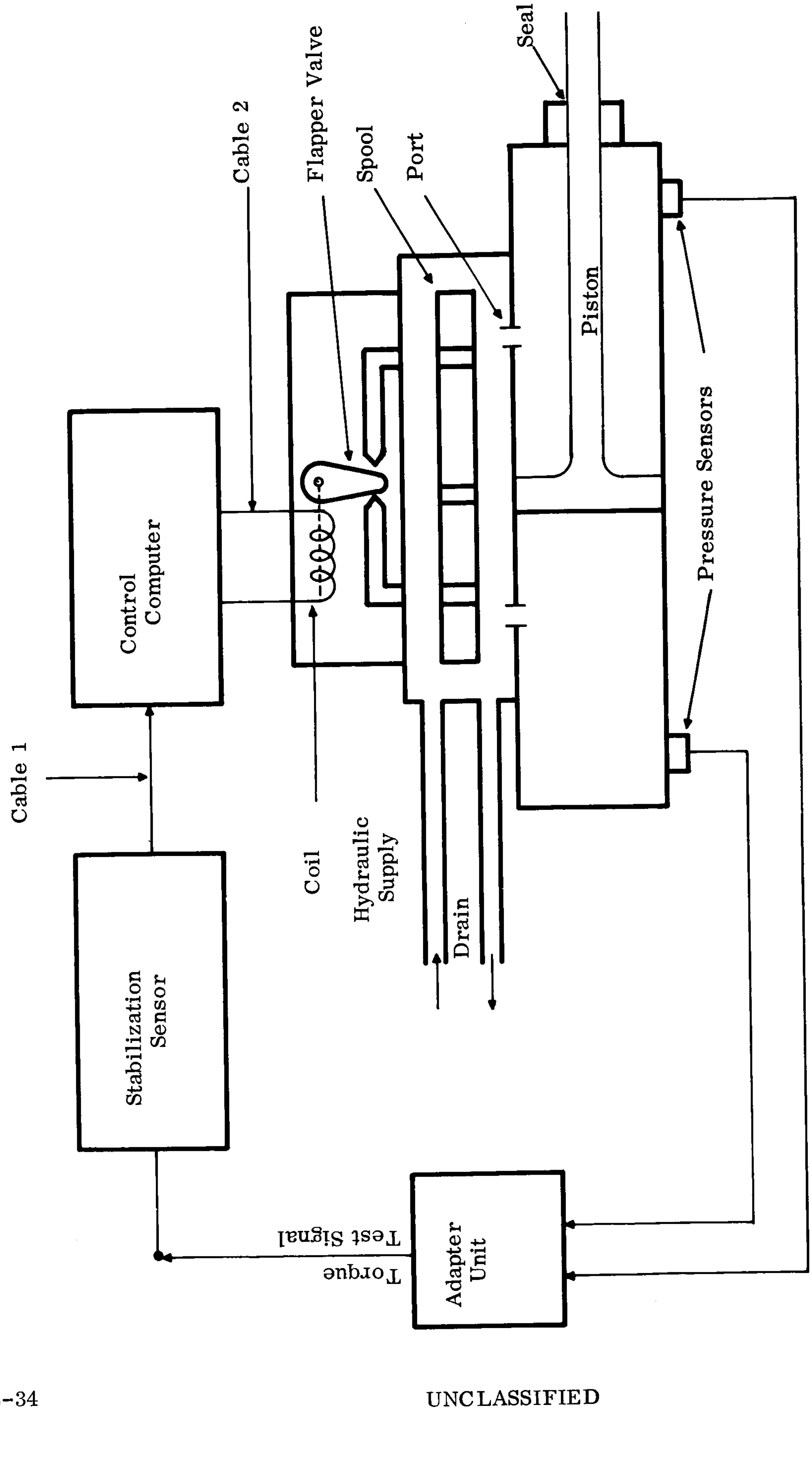


Figure 3-8. Control System Block Diagram Showing Torque Tests and Pressure Sensors

The application of a given torque test signal causes a sensor output. This signal serves as an input to the control computer through cable 1.

The control computer will provide an output through cable 2 to the actuator coil. The actuator coil operates the flapper valve which, in turn, causes the spool to move. The spool motion uncovers ports which allow flow from the hydraulic supply through the main cylinder. This differential is detected by the two sensors.

A signal at these pressure sensors checks the continuity of the paths between the gyro and the actuator. Note that this includes the connectors and cables between the control system's units and between the vehicle stages.

The checkout described here can readily include the astronaut's checkout of his mode selectors in the case of the C/M control stick inputs and backup modes as programmed by the computer test routines.

Figure 3-9 illustrates the adapter implementation concept for a "typical" control system, the following paragraphs reference this diagram.

Control signals are sent from the adapter controller to the signal routing matrix and to the buffer memory of the stimuli generators. The signal routing matrix provides for the selection of the particular parameter to be evaluated and for the appropriate signal conditioning (scaling, conversion to dc, etc.) of this parameter. A dc voltage representing the parameter under test is sent to the digitizer where it is converted to a digital word and placed in buffer storage to be transferred serially to the adapter controller.

The stimuli-generator buffer memory provide for the selection of the appropriate frequency, amplitude, and/or phase shift for required input stimuli. One output of the phase shifter is provided as a reference to the signal conditioner. Inputs to the signal conditioner are shown from the stabilization and instrumentation sensors, from the power suppliers, and from the control computer (analog).

3.3.2 LAUNCH-VEHICLE COMPUTER

It is assumed that the launch-vehicle computer program can be readily changed and that test programs can be read into the computer for checkout purposes.

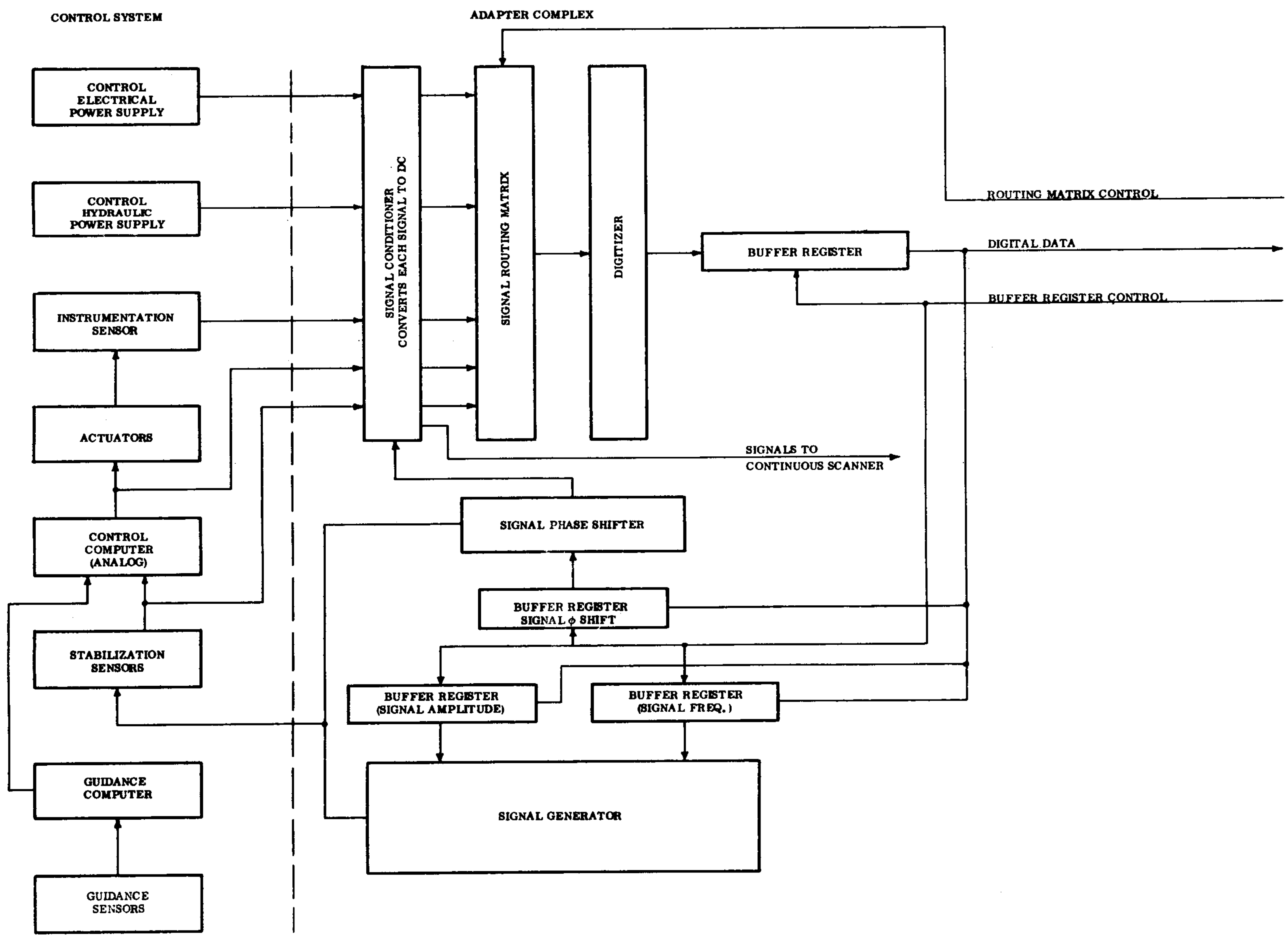


Figure 3-9. Adapter Implementation Concept for Control System

The computer will be turned on by the guidance-signal processor. The timing relationship of the computer turn-on sequence will be checked by discrete signals from the computer. This type of test will be made to indicate any deterioration of components in the sequence generator. Once the computer is on, the d-c power and the 2ϕ drum power will be measured to detect changes in computer power converter and drum operation.

Certain data stored in memory must not be lost when the computer is turned on and off; this function will be checked as soon as the computer is turned on by comparing this stored data with the "limits" provided by the adapter controller. The data recalled from both the vehicle computer and the adapter controller will have error-detecting bits, so that if a failure is indicated it can readily be isolated to the vehicle equipment or the test equipment.

Once the computer is turned on, a test program will be read into the computer and verified by reading it back; the test program will exercise the arithmetic element and the memory to determine if the digital computer is functioning correctly. If there is an indication of a failure, the program will continue into a diagnostic routine to isolate the failure. (The isolation routine will be performed primarily to assure that the failure actually exists in the prime equipment and is not due to a test equipment failure.)

If an analysis shows that it will increase the confidence level, provision will be added to vary the amplitude of the computer power supply and the computer clock pulses. The computer would then be exercised by the test program with power at extreme upper and lower limits. A failure on this type of test would indicate that some component was nearing end of life (such as the gain of a circuit deteriorating our of limits).

Such things as the computer power converter, clock-pulse characteristics, and analog inputs and outputs will be checked if the analysis shows they will increase the confidence level of the vehicle computing system.

The input encoders will be checked by causing known inputs, such as platform attitude and velocity increments, to appear on the analog side of the encoders and reading the digital value out through the vehicle computer to the checkout equipment.

The decoders (digital-to-analog converters) will be checked by programming the computer to supply known digital numbers to the encoder and checking the analog output.

Once the computer has been checked out, the launch program will be read into memory and verified. A small section of this program can be a test exercise to be continuously monitored when the computer is on during the final stages of the countdown. Simulated missions can be used to check as much of the guidance system as possible.

Figure 3-10 illustrates the adapter implementation concept for the launch-vehicle computer.

3.3.3 INERTIAL PLATFORM SUBSYSTEM TESTS

The tests and the equipment described in the following section are intended to test the inertial platform subsystems, consisting of platform and platform electronics, and of the various guidance systems after vertical assembly has been completed. The nature of several of the tests requires that the equipment accomplish erection, alignment, and gyro trim. Tests are divided into three main groups: (1) static tests, (2) operation tests, and (3) performance tests.

3.3.3.1 Static Tests

- <u>Air Flow Test (L/V Platform Only)</u> - It is necessary to insure that gyro and accelerometer rotor bearings are receiving an adequate supply of air before applying electrical power. Both pressure and flow measurements should be made.

- <u>Check Electrical Power</u> - All excitation voltages should be measured prior to application of power. This includes pickoff excitation voltages, gyro and accelerometer spin motor voltage, amplifier voltages, etc.

  If all voltages are correct, power is applied in a predetermined sequence. Current is measured in gyro and accelerometer spin-motor lines.

  After spin-up time has passed, gyro and accelerometer spin-motor speed should be checked. There are several methods of accomplishing this: some gyros have a separate pickoff output proportional to speed, otherwise a Lissajous pattern, formed by the motor voltage and supply voltage, can be used.

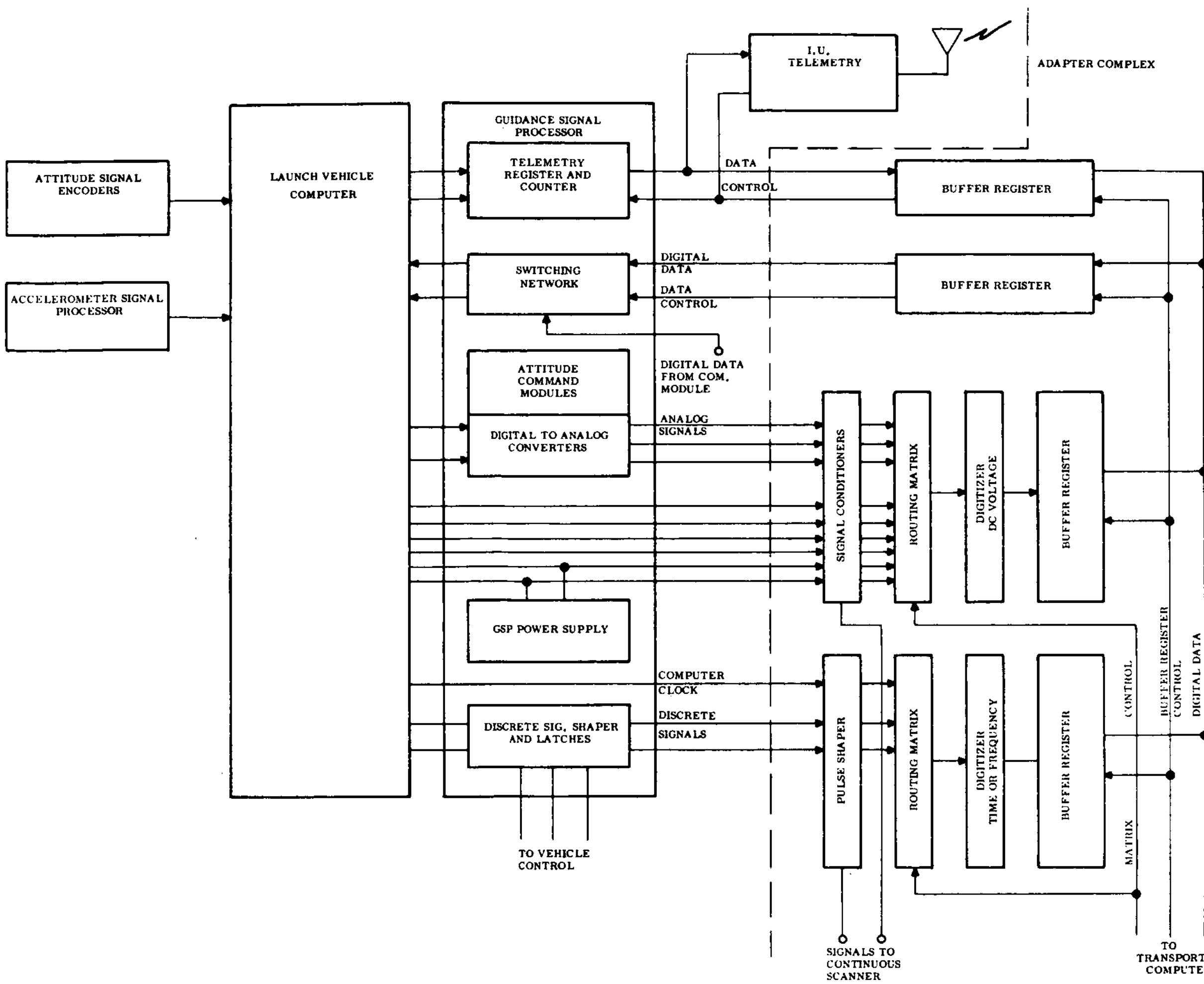


Figure 3-10. Implementation Concept for Launch Vehicle Computer

- Temperature Tests - Temperature indicators are tested by simulating their input. For example, if proportional gyro temperature control is used, a resistor can be used to simulate the internal temperature sensor at operating temperature. After temperature indicators are checked, the inertial sensors internal temperatures and platform-case temperature should be measured. These measurements should use separate temperature sensors, not the sensors being used for temperature control.

3.3.3.2 Operation Tests

- Erection and Alignment - Using the test equipment controls and whatever azimuth reference is to be used, the platform is aligned and erected. At this time, null-voltage readings within the present tolerance should be measured on outputs of the gyros, pendulums, gimbal pickoffs, and the two leveling-loop accelerometers. The third accelerometer sensitive axis should be vertical; its output should correspond to a 1-g acceleration. A deviation from these voltages indicates misalignment or a component failure.

- Gyro Trim - At the conclusion of alignment and erection, the steady-state gyro torquer currents, supplied by the erection alignment amplifiers, should be measured. This current is proportional to gyro drift. To trim this drift, the corresponding value of torquer current for each gyro is supplied from a trim pot. This should reduce the erection and alignment amplifier currents to a null value within a pre-set tolerance. Gyro drift can be verified directly by disabling the erection and alignment loops and allowing all three gyros to operate as free gyros. Gimbal rotation is measured for a given time. This, in turn, provides gyro drift rate. Total gimbal rotation in this test is limited so that earth's rate will not contribute much error. Gimbal rotation can be measured in several ways: (1) optically, (2) through gimbal pickoffs, or (3) for the two horizontal channels through accelerometers or pendulums.

Tests to this point indicate that the platform is operating. However, neither accuracy nor dynamic performance have been established. This is the purpose of the next series of tests.

3.3.3.3 Performance Tests

- Gyro Torquer and Accelerometer (Scale Factors) - Applying a precise gyro torquer current for a precise length of time should drive the platform gimbal through a known angle. In pitch and roll, this tilt angle will result in a known accelerometer output. The vertical accelerometer and yaw gyro can be tested in the same manner by first rotating 90 degrees about either the pitch or roll axes, thereby interchanging yaw with roll or pitch, respectively. Earth's-rate correction signals are adjusted to correspond to the new gimbal position. An accelerometer output outside the tolerance indicates either accelerometer or gyro torquer scale factor is incorrect.
- Gimbal Pickoff Test - In the tilted positions of the previous test, measure the gimbal pickoff output voltages. These voltages should correspond to predetermined values within a pre-set tolerance.
- Base-Motion Isolation-Loop Response - In this test, the dynamic response of each base-motion isolation loop is measured. In each channel, a step voltage input is applied to the servo amplifier. This step should be small enough to allow the amplifier to operate in its linear region. The gyro pickoff output voltage is measured or recorded. Both the voltage peak and decay characteristic should be within prescribed limits.
- Accelerometer Servo-Loop Response - The above test is repeated for the accelerometer servo loops. Both the peak value and decay characteristic of the error voltage should be within prescribed limits.

This completes the checkout of the platform and platform electronics. After these tests have been completed, the platform subsystem performance is continually monitored, although all the previous tests need not necessarily be repeated. Performance monitoring is accomplished through the following tests:

- Measure static quantities, supply voltages and currents, air flows, component temperatures, etc.
- With the platform erect and aligned, measure the outputs of the gyro pickoffs, accelerometers, and pendulums. These should all be null readings with the exception of the vertical accelerometer; Figure 3-11 illustrates an adapter implementation concept typical platform.

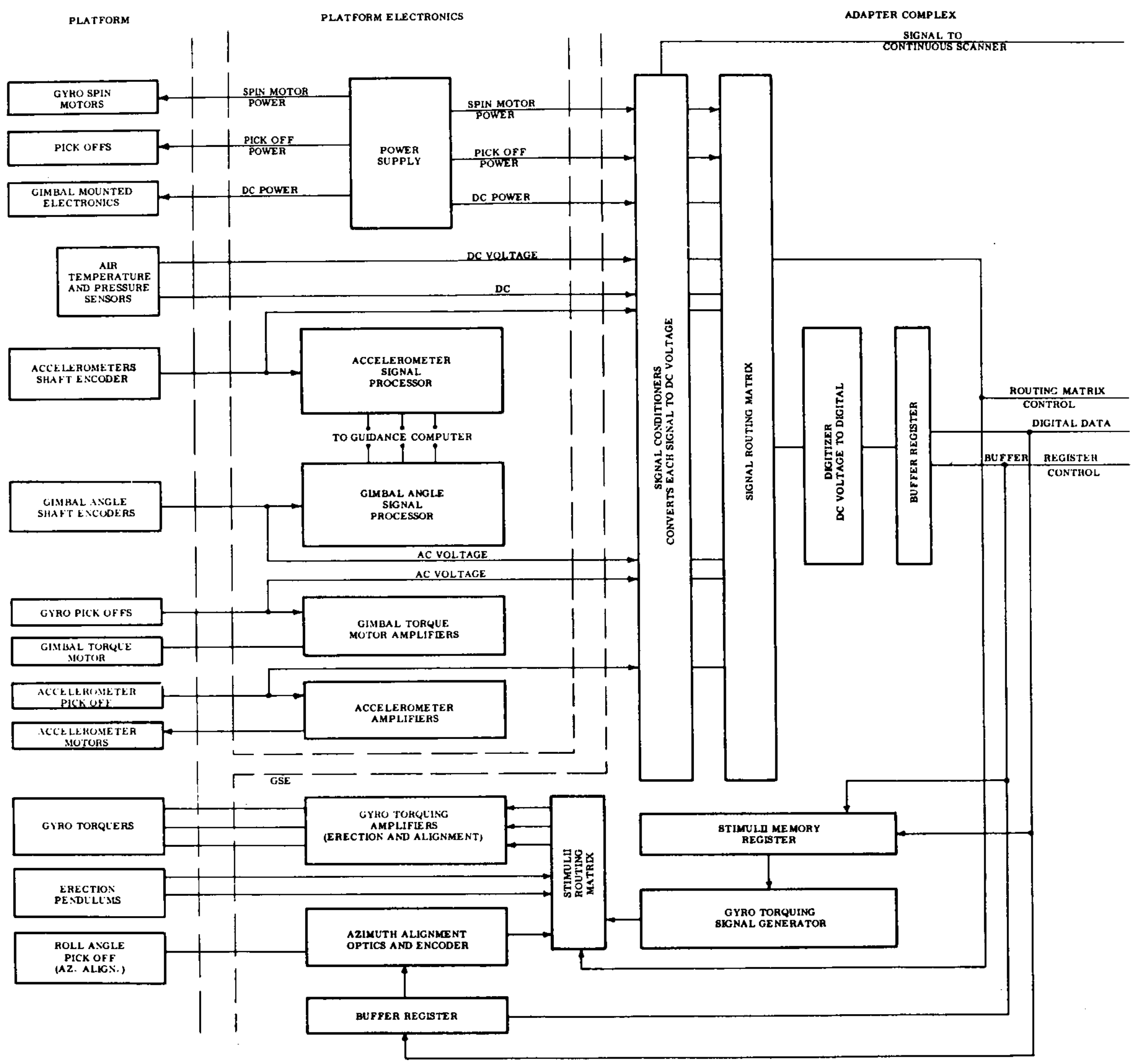


Figure 3-11. Adapter Implementation Concept for Typical Platform

3.4 PROGRAM PLAN

The matrix shown in Figure 3-12 presents a list of assumptions which have been made in generating the conceptual model of the vehicle Integrated Checkout System, together with a listing of the studies required to verify or modify these assumptions. Figure 3-13 indicates the recommended schedule and estimated duration of these studies.

The following information may be derived from this matrix:

- The number of study areas which must be examined to confirm an assumption is apparent.
- If a given study is being planned, an outline of what the study must prove can be obtained from the related assumptions.
- The matrix can be used as a checklist to assure that the program is not advancing too far ahead of unverified assumptions.

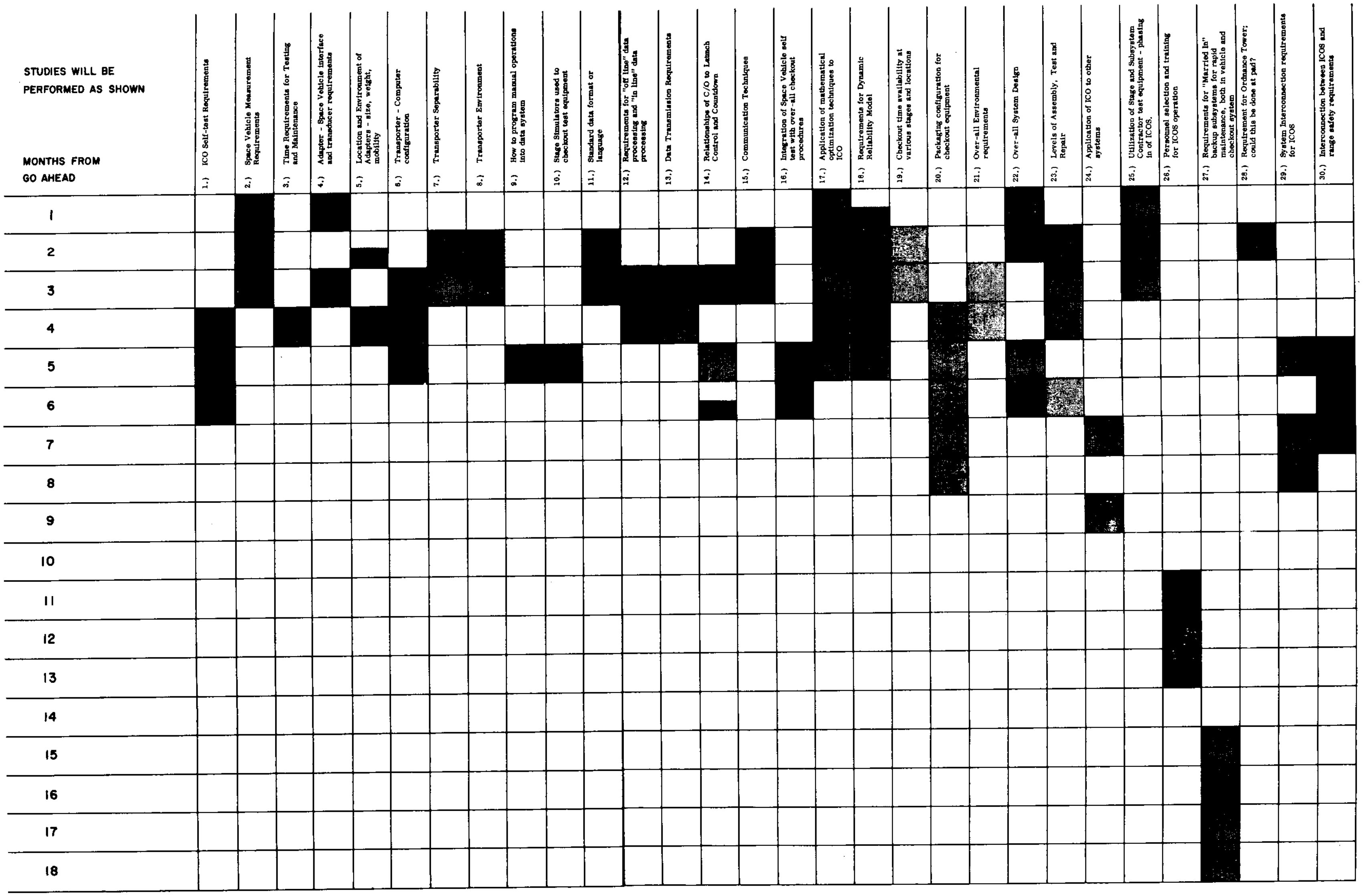


Figure 3-12. Matrix of Assumptions Made in Generating the Conceptual Model of the Vehicle Integrated Checkout System, with Studies Required to Verify or Modify

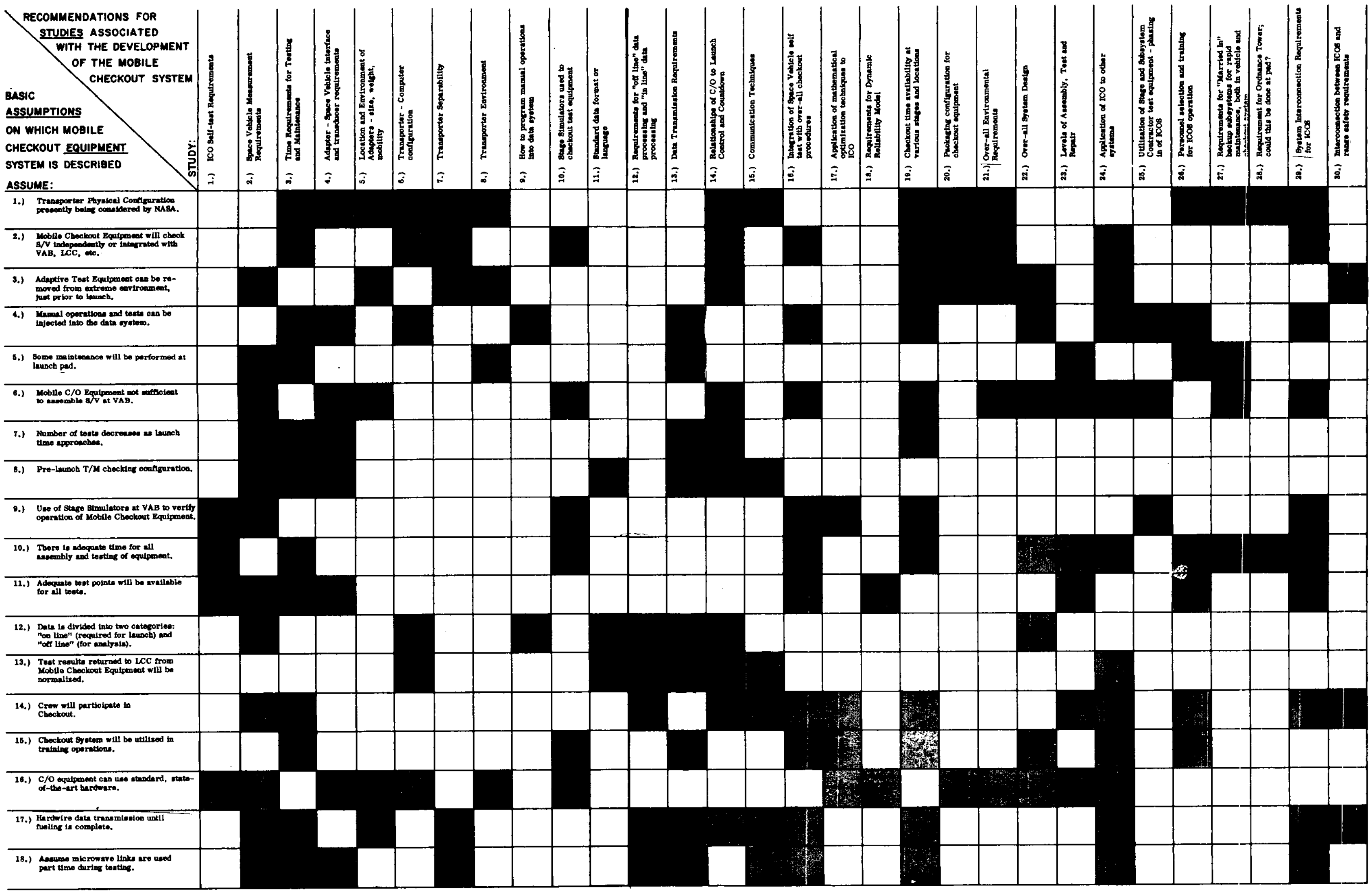


Figure 3-13. Matrix of Recommended Schedule and Estimated Duration of Studies

SECTION 4
LAUNCH CONTROL CENTER

4.1 INTRODUCTION

4.1.1 PURPOSE AND SCOPE

The purpose of this section is to describe requirements and present an implementation concept for the Apollo Launch Control Center. The concept presented is based on a preliminary analysis of requirements. The commitment to a final design phase will necessitate additional system analyses and the establishment of a preliminary design program to define design requirements in detail. This program will consider the Launch Control Center as an element within the total Apollo equipment and personnel complex, whose performance must be optimized to insure successful space-vehicle launching.

In Sections 4.2 and 4.3 below, the functional requirements and the implementation concept for the Launch Control Center are outlined. The implementation concept provides a general description of the Launch Control Center and its interfaces, its operating characteristics, and its internal equipment. The functional requirements are based on assumptions about the lunar mission profile and the configuration of facilities at the Atlantic Missile Range, which are discussed below.

4.1.2 ASSUMPTIONS

4.1.2.1 Lunar Mission Profile

It is assumed that the Launch Control Center will be required to support either a lunar-orbital-rendezvous or direct-ascent mission. It is further assumed that either of these missions will require the Launch Control Center to operate with two space vehicles during the period of postassembly launch operations, with one of the vehicles serving a back-up function.

4.1.2.2 Atlantic Missile Range Facilities

The following assumptions have been made regarding facilities at the Atlantic Missile Range.

The location of the Launch Control Center will be sufficiently remote from the launch area to permit its being a non-hardened facility.

Final space-vehicle assembly will take place within a Vertical Assembly Building, where individual vehicle stages will be assembled on a transporter-launcher. Upon completion of assembly and commitment to a flight, each space vehicle will be transported several miles to the launch area.

Located approximately midway between the Vertical Assembly Building and launch area will be an ordnance tower, where pyrotechnic devices will be installed.

Four launch pads will be provided. Launch-pad facilities will include fueling provisions, communications terminal equipment, general utilities, transporter-launcher interface terminal equipment, and checkout and monitoring equipment for these facilities.

4.2 LAUNCH CONTROL CENTER FUNCTIONAL REQUIREMENTS

4.2.1 LAUNCH OPERATIONS CENTRAL CONTROL

Planning and controlling the many activities associated with the Apollo launch operation will represent a highly complex and challenging management problem. The launch operation cycle for each space vehicle will include assembly and checkout in the Vertical Assembly Building, transportation to the launch pad, preparation for launching on the pad, launching, and the evaluation of vehicle performance during the initial flight period. The over-all launch operation task will be complicated by the fact that several space vehicles having different flight objectives must simultaneously be prepared for launching.

It will be a function of the Launch Control Center to facilitate the management of this complex task by centralizing the collection and presentation of essential data for launch operations personnel. This data will provide the following information:

- Detailed definition of the sequence and interdependencies of the numerous tasks and events comprising the launch operation cycles.

- Required completion schedules for the tasks and events.
- Completion status for all tasks and events.

4.2.2 POSTASSEMBLY LAUNCH OPERATIONS

The Launch Control Center will be the central point for operations during the postassembly launch period. Basic prelaunch functional requirements for the Launch Control Center may be summarized as follows:

- Over-all control of the simultaneous countdowns for two space vehicles.
- Control of individual space-vehicle prelaunch checkouts.
- Initiation and monitoring of space-vehicle fueling operations.
- Coordination of prelaunch activities with the Mission Control Center.
- Recording of prelaunch data.
- Initiation and monitoring of space-vehicle firing sequences.

The mobile checkout subsystem on the transporter-launcher will be self-sufficient and capable of operating either under local control or under remote control from the Launch Control Center. Prior to loading hazardous fuels and oxidizers, the transporter-launcher will be manned and space-vehicle checkout equipment may be operated locally. During local control, checkout operations may be monitored from the Launch Control Center to insure that established routines are followed.

Once hazardous fueling operations begin, the transporter-launcher will be unmanned, and the Launch Control Center will provide remote control and monitoring of all space-vehicle operations for the remainder of the countdown.

The Launch Control Center must be able to accommodate emergency situations during the prelaunch phase. Possible emergency situations might include:

- Fires or explosions on the pad.
- Critical ground equipment malfunctions, such as power failure during fueling operations.
- Failures on the space vehicle which could create hazardous conditions.

The prelaunch countdown must be preceded by a system loop check involving the Launch Control Center, transporter-launcher, space vehicle, ordnance tower, and launch-pad facilities. This check will be performed while the space vehicles are in the Vertical Assembly Building.

4.2.3 INITIAL FLIGHT PHASE OPERATIONS

During the initial flight phase, both the Launch Control Center and the Mission Control Center will be required to monitor space-vehicle performance to evaluate its mission capability. The results of the initial flight phase evaluation will be factored into an over-all evaluation of mission capability, from which a decision to abort the flight or modify the mission may result.

The initial flight phase monitoring function will require analysis of vehicle trajectory parameters, supplied by the Atlantic Missile Range tracking facilities. In addition, it will be necessary to receive and analyze critical telemetry parameters. These analysis functions will require programmed real-time computation and display of data necessary for decision making.

Trajectory evaluation for mission-capability analysis will be distinct from the range safety trajectory evaluation, which will be under the administrative control of the Atlantic Missile Range.

4.2.4 FUNCTIONAL DESIGN REQUIREMENTS

The complexity of prelaunch and initial flight phase operations will demand that a high degree of automation be designed into the Launch Control Center equipment. This automation must be provided with no sacrifice in operating flexibility. The degree of flexibility must permit:

- Rapid and efficient preparation of automatic control programs.
- Ease of program modification.
- Optional manual control of functions.
- Growth potential and modification flexibility to accommodate changing mission requirements.

A critical problem in the design of Launch Control Center equipment will be that of satisfying Apollo availability requirements; therefore, a thorough analysis will be made of this problem. Initially, this analysis will establish the required Launch Control Center availability as a function of mission and launch-rate requirements, and, finally, it will determine a Launch Control Center design that best meets the availability requirements. Attainment of the required availability level will require that benefits from the addition of special, built-in diagnostic features and/or redundancy be traded off against the higher reliability offered by minimum equipment complexity.

4.3 LAUNCH CONTROL CENTER IMPLEMENTATION CONCEPT

4.3.1 GENERAL DESCRIPTION

The Launch Control Center, as conceived, will be divided functionally and physically into two major areas: (1) an operational area, and (2) an area for the Launch Operations Control Center. The operational area will permit real-time control of post-assembly launch operations. The Launch Operations Control Center will facilitate over-all management of launch operation activities, including assembly and checkout operations in the Vertical Assembly Building.

Figure 4-1 is a functional block diagram of the Launch Control Center, which shows the primary input-output interfaces and the relationships between major equipment subsystems. A simplification of this block diagram is shown in Figure 4-2. All of the blocks shown, with the exception of the Launch Operations Control Center, will be involved with the performance of postassembly launch operations. These operations will require that the mobile checkout subsystem on the transporter-launcher be adaptable to remote control from the Launch Control Center, as well as capable of independent operation. Also required will be the capability for remote operation of launch-pad checkout and fueling equipment and for remote control and monitoring of certain ordnance tower functions. As shown in Figure 4-1, remote operation will be accomplished by means of two-way digital control data links from the Launch Control Center to the Vertical Assembly Building, ordnance tower, and launch pads.

Space-vehicle telemetry data links will permit real-time evaluation and recording of vehicle performance during the initial flight phase. They also will permit checkout of the telemetry system, as well as provide verification of data received from the mobile checkout subsystem during the prelaunch period. Additional data links will include:

- A one-way data link from the Atlantic Missile Range tracking facilities to obtain data for initial flight phase trajectory evaluation.
- A two-way data link to the Mission Control Center for over-all mission coordination functions. (Launch operations status data, including initial

flight phase evaluation data, will be transmitted to the Mission Control Center over this link.)

- A two-way data link to the Checkout Data Evaluation Center to be used for the transfer of selected checkout data and data-evaluation results.

The Launch Control Center will be capable of simultaneous monitoring and control of two space vehicles during the postassembly period prior to launching. The data translator subsystem, as the terminal point for all digital data links, will provide the necessary input/output data link selection. This subsystem will also encode, decode, decommutate, and synchronize data for the digital data processor subsystem.

The digital data processor subsystem will provide centralized storage and/or data routing for the Launch Control Center. In addition, it will perform prelaunch and postlaunch computations. All control and data signals between subsystems will be in a digital format and will be routed through the digital data processor. This method of handling data will offer the flexibility necessary to minimize the effects of probable changes in space-vehicle configuration from flight to flight.

The launch control and display subsystem will provide control and monitoring consoles from which operating personnel may exercise control of postassembly launch activities. As shown in Figure 4-1, dual-channel control will be provided to accommodate the simultaneous countdown of two space vehicles. Each channel will consist of stage/system consoles under the supervision of a test conductor. Stage/system consoles will provide the controls and associated displays necessary to perform a complete checkout of each space vehicle. In addition, support and service functions of the launch pad will be controlled and monitored from these consoles. The test director consoles will allow control of the complete launch operation. Included in the functions performed will be monitoring of flight dynamics, pad safety control, and coordination with the Mission Control Center, and the Atlantic Missile Range.

The communication subsystem will accommodate the reception, transmission, control, and distribution of voice and television communication functions. Subsystem functions will include UHF and HF spacecraft communication, administrative internal and external voice links, and remote television monitor control and signal distribution.

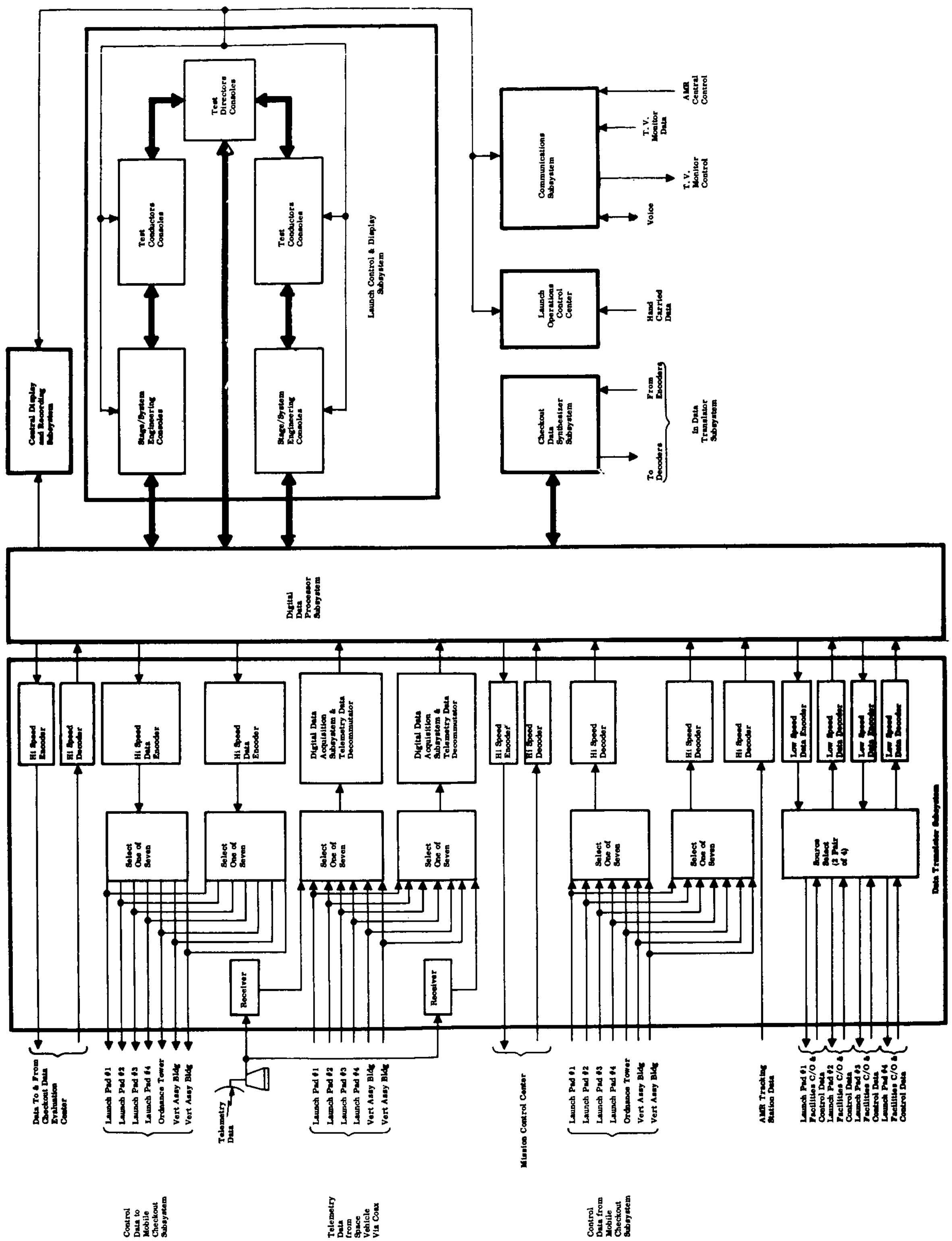


Figure 4-1. Launch Control Center Functional Block Diagram

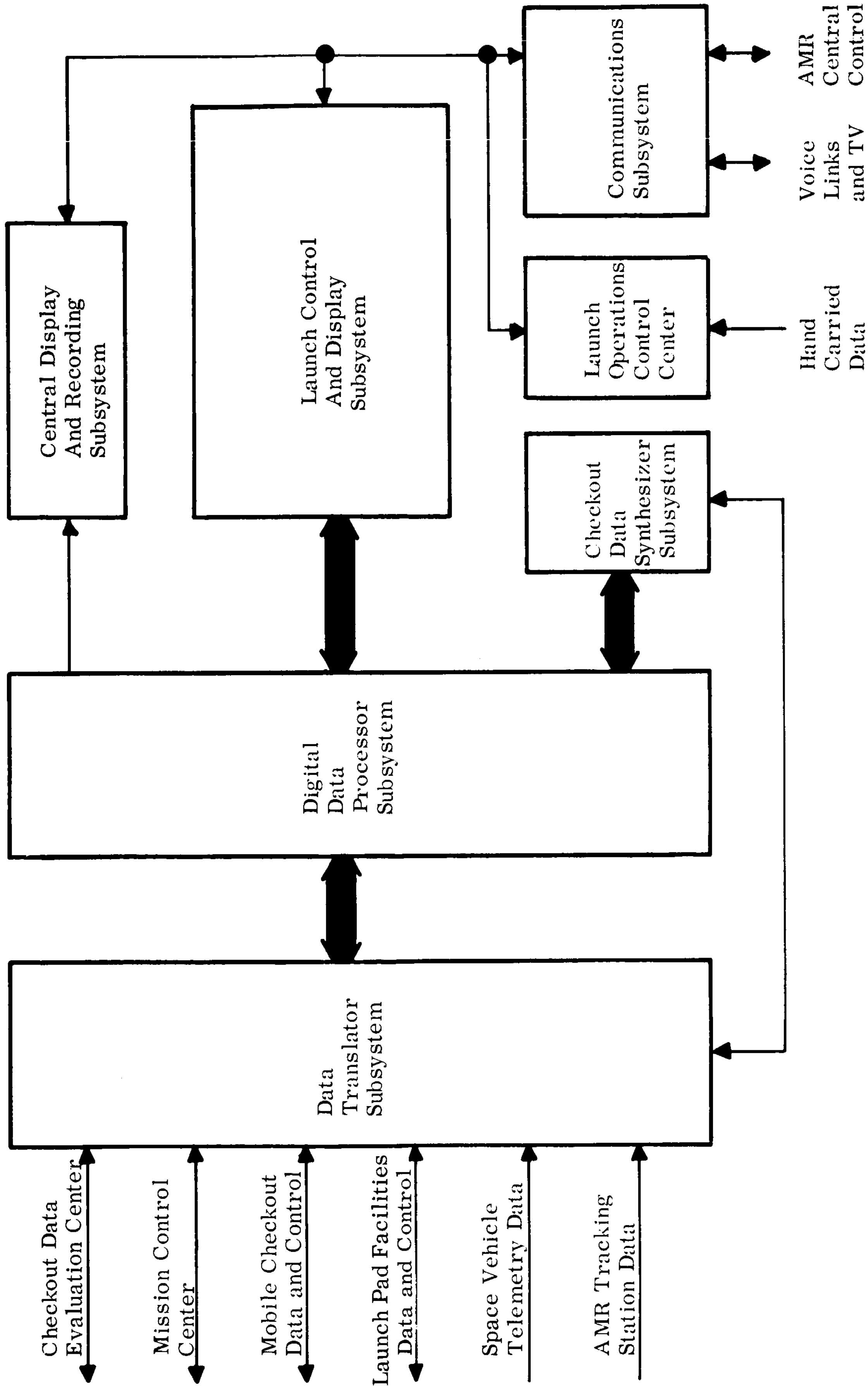


Figure 4-2. Launch Control Center Simplified Block Diagram

The central display and recording subsystem will consist of launch-operation summary status displays, and data tabulation and recording equipment. This subsystem will provide a centralized recording facility, containing both analog and digital recording equipment, which will produce recordings for both quick-look and routine post-flight evaluations.

Maintenance operations within the Launch Control Center will be facilitated through use of the checkout data synthesizer subsystem. It will provide the capability of simulating Launch Control Center inputs, such as those from the data links. When this subsystem is operated in its automatic mode, it will be under control of the digital data processor, and the responses of the Launch Control Center equipment will be evaluated automatically. A capability for manual control of the checkout data synthesizer will also be provided.

The second of the two major areas within the Launch Control Center will contain the Launch Operations Control Center. Briefly, this center will provide a display of operations-status data which can be used by launch operations personnel for managing all phases of launch operations. The specific means for mechanizing these displays is a subject for further study. A concept being considered would employ projection techniques for display of PERT* charts and other detailed status information.

A representative floor plan for the operating portion of the Launch Control Center is shown in Figure 4-3. The area on the left shows the location of the Launch Operations Control Center. The remaining area contains the operational consoles and displays, as well as unattended equipment used in the postassembly operations. An artist's concept of the operational area is shown in Figure 4-4.

4.3.2 SUBSYSTEM DESCRIPTIONS

4.3.2.1 Data Translator

Launch Control Center equipment will be tied by digital data links to remote equipment located at the Vertical Assembly Building, ordnance tower, launch pad, and mobile checkout subsystem. Functionally, the data links will be divided into two kinds:

---

* Program Evaluation and Review Technique

checkout and control links, and telemetry data links. These links will operate in parallel to provide data-link confidence checks. Data entering and leaving the Launch Control Center will be processed by the data translator. The specific function of the data translator will be to:

- Translate checkout and control data from the digital data processor into suitable formats for transmission.
- Translate information received from the checkout and control links into a form suitable for the digital data processor.
- Translate vehicle telemetry signals into a form suitable for the digital data processor.

Each of the checkout and control links will be fed by an encoder/transmitter. The encoders will format data, serialize parallel data from the digital data processor, and modulate a transmitter carrier. The decoder, after receiving the transmitted data, will provide serial-to-parallel conversion and special formatting of the data, as required. The data to be handled by checkout and control links will consist, typically, of checkout program instructions, qualitative and quantitative test results, and all other data required to monitor and remotely control the mobile checkout subsystem and pad facilities during the countdown operations.

Telemetry data received at the Launch Control Center will be processed by a typical telemetry ground station. The telemetry data may arrive by either coaxial line or RF air link. This data will permit real-time, prelaunch, and postlaunch monitoring, and will provide a verification of test results received from the mobile checkout subsystem over the checkout and control data link. The output of the telemetry data link will be recorded, processed by the digital data processor, and/or displayed on the monitoring consoles.

4.3.2.2 Digital Data Processor

The function of the digital data processor at the Launch Control Center will be to route and store data, program prelaunch operations, and make postlaunch computations. It will be required to accomplish the simultaneous countdown of two space vehicles, provide the flexibility of either manual or automatic sequence control, process checkout test requests, establish request priorities, make vehicle trajectory computations after launch, recommend continuation, modification, or abortion of the flight as a function of space-vehicle performance, and predict the point of impact if the flight is to be aborted.

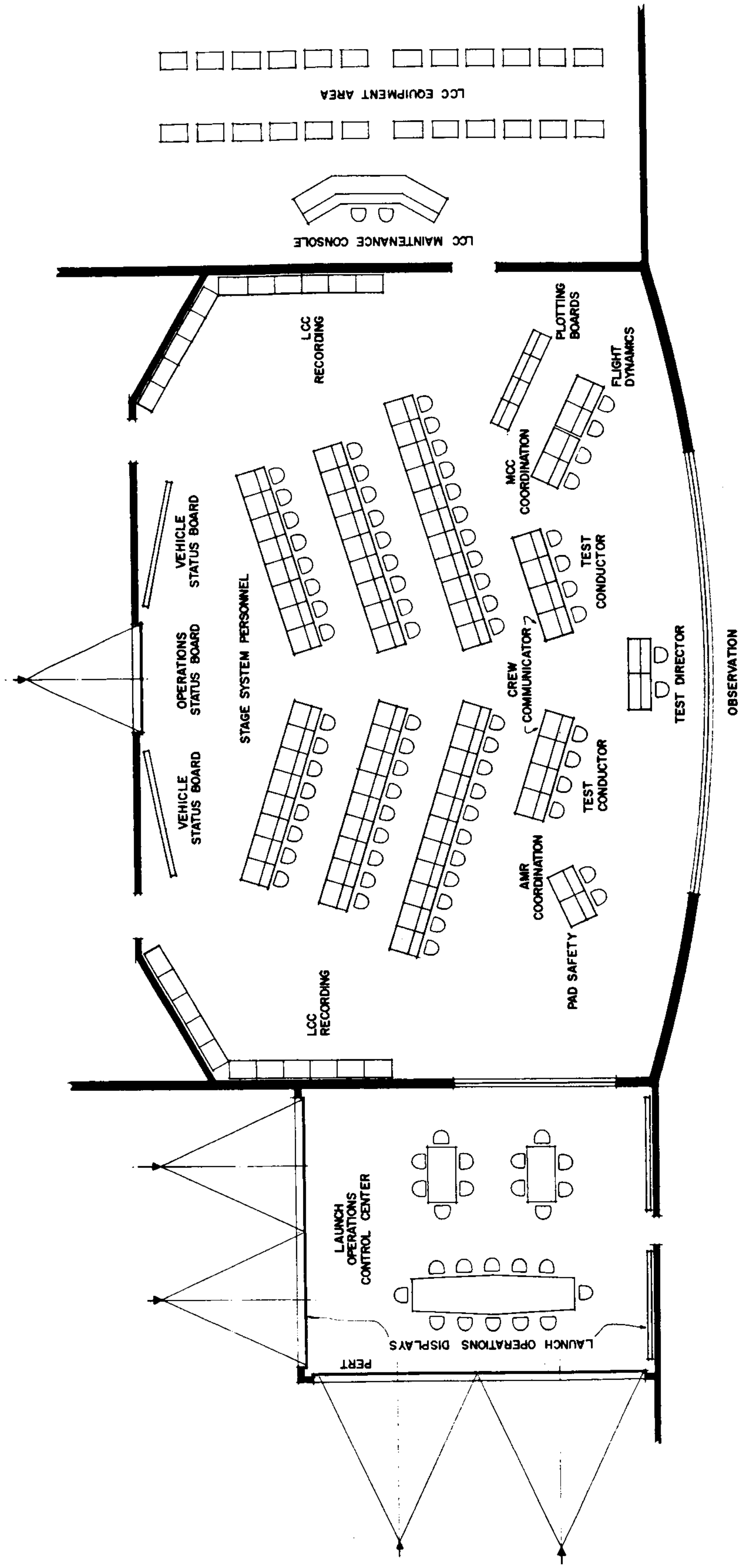


Figure 4-3. Floor Plan for Launch Control Center Operating Area

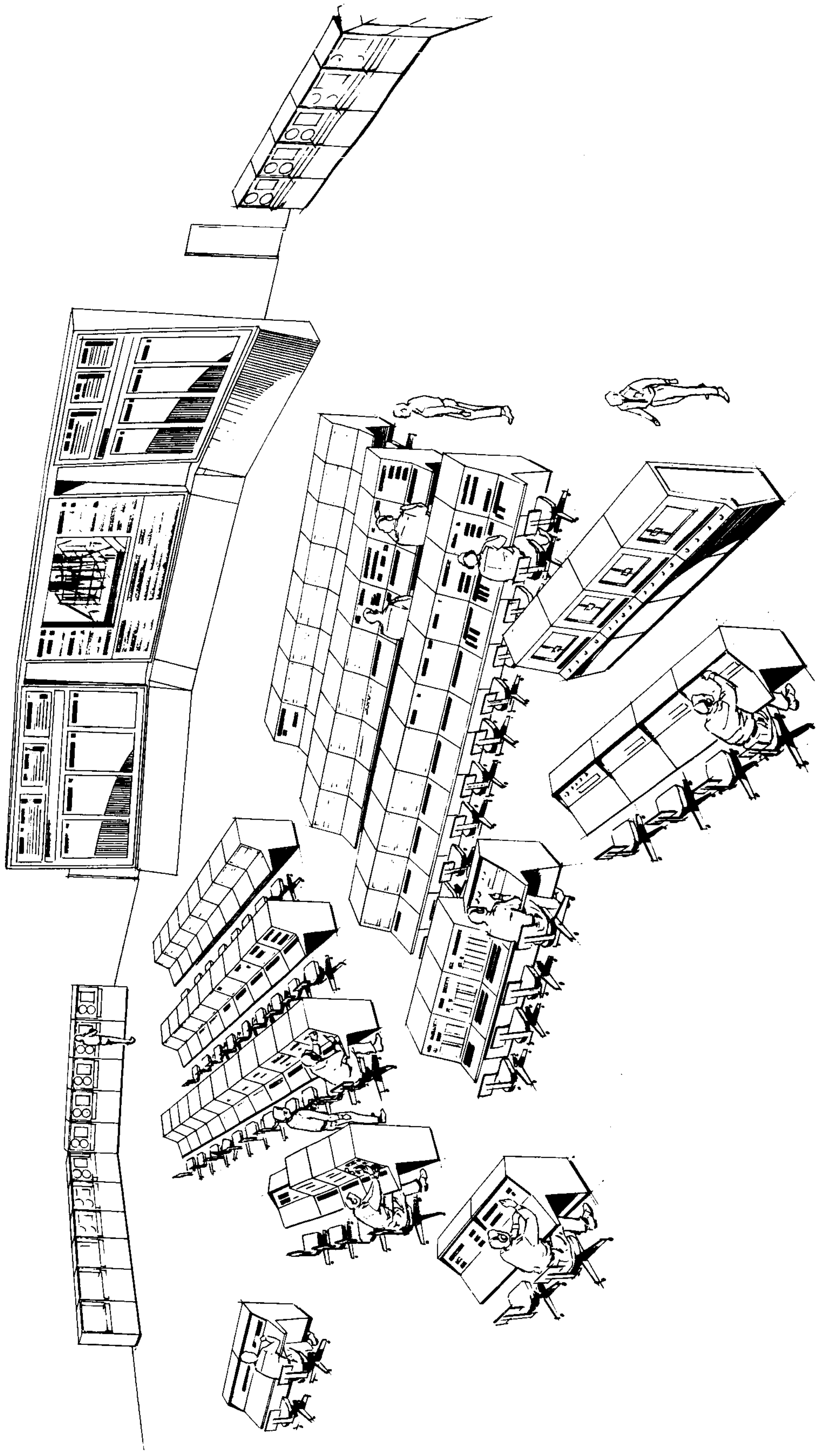


Figure 4-4. Launch Control Center Operating Area

Since it is anticipated that the Launch Control Center requirements will change from flight to flight as the Apollo program matures, the Launch Control Center digital data processor must provide extreme flexibility, sufficiently high computation rate, and expansion capability to meet present and future Launch Control Center real-time data-processing requirements. To satisfy these requirements, the digital data processor will be a computer complex featuring modular construction. It will be expandable by the addition of modules which do not require equipment replacement or extensive system redesign.

A typical digital data processor configuration, consisting of three standard module types, plus standard peripheral devices, is shown in Figure 4-5. This illustration is presented only to demonstrate the system flexibility; and not to suggest the number of modules required.

The minimum system configuration shown would require only one memory module and one arithmetic module, and would resemble a conventional digital computer with seven asynchronous data channels, but no peripheral devices or equipment redundancy. To what extent the digital data processor would be expanded beyond the minimum system would depend on a thorough analysis of the Launch Control Center data-processing requirements.

The digital data processor storage capacity could be expanded by connecting additional memory modules and/or bulk storage devices to existing system modules, using standard data-channel plug-in connectors and cabling. Computing capacity could be expanded by connecting additional arithmetic modules; the number of available data channels could be increased by connecting additional data-channel multiplex modules to existing data channels. In general, the digital data processor configuration could be modified by adding or deleting modules and/or connecting or reconnecting any or all modules to provide the desired relationships.

If the digital data processor configuration is to be modified, the digital data processor program may be modified to reflect the change. To minimize the programming effort, the Launch Control Center program may be developed in modules, or subfunction routines, so that only the executive control routine and the affected operational routines need be revised.

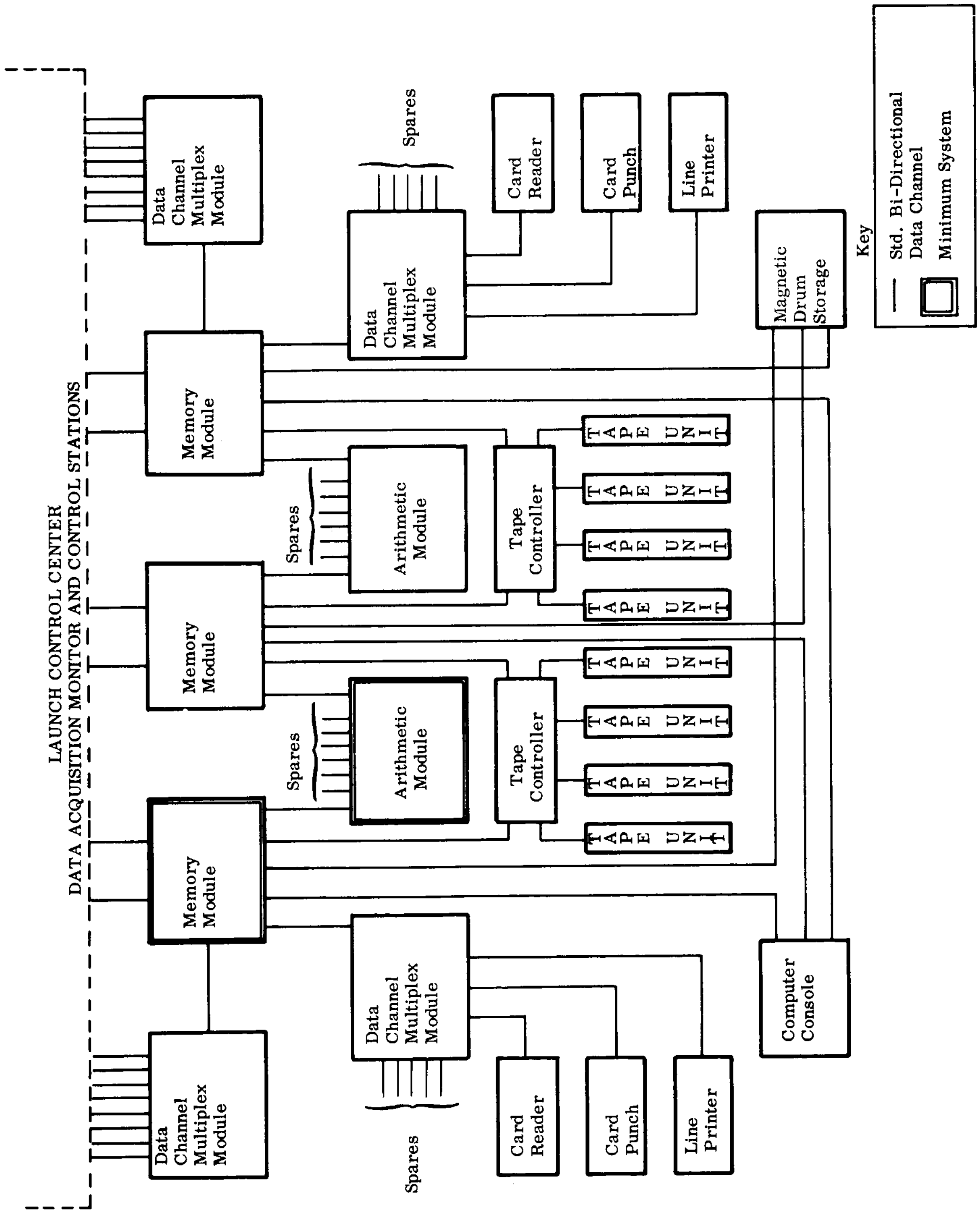


Figure 4-5. Digital Data Processor Configuration

Regardless of the digital data processor configuration selected, the executive control routine will be the executor, or master controller, that controls the sharing of the computer time for use of the subroutines. To assure that a number of vehicles may be brought simultaneously to the firing point, it will be a function of the executive control routine to assure strict adherence to the time cycle. Since requests for use of subfunction routines may be made randomly by the subsystem engineers, it will be necessary that priorities be established and controlled by the executive control routine. The executive control routine will therefore control the major Launch Control Center countdown and checkout operations.

The subfunction routines will accomplish parts of the over-all control, monitoring, and data-logging requirements for the Launch Control Center. These routines also will execute specific requests for tests and operations to be performed by the mobile checkout subsystem and other remote equipments.

4.3.2.3 Launch Control and Display

During the postassembly, launch, and initial flight phases, real-time launch operations will be controlled and monitored by the launch control and display subsystem. This subsystem will consist of consoles, display devices, and associated equipment that will operate in conjunction with other subsystems, as indicated by Figure 4-6.

A representative layout for the operational area in the Launch Control Center is shown in Figure 4-3, and an artist's concept of the same area is shown in Figure 4-4. In this layout, the consoles have been arranged in groups which correspond to the activities of the test director, test conductor, and stage/system personnel.

The test director consoles will provide over-all control and monitoring of launch functions for two space vehicles; these functions will include monitoring of flight dynamics, pad safety, Mission Control Center coordination, and Atlantic Missile Range coordination.

To allow for the simultaneous countdown of two space vehicles, duplicate sets of test conductor consoles will be provided. Each set will permit control and monitoring of over-all launch functions for one space vehicle. These functions will include monitoring of the countdown sequence, evaluation of flight performance, and communications with the spacecraft crew.

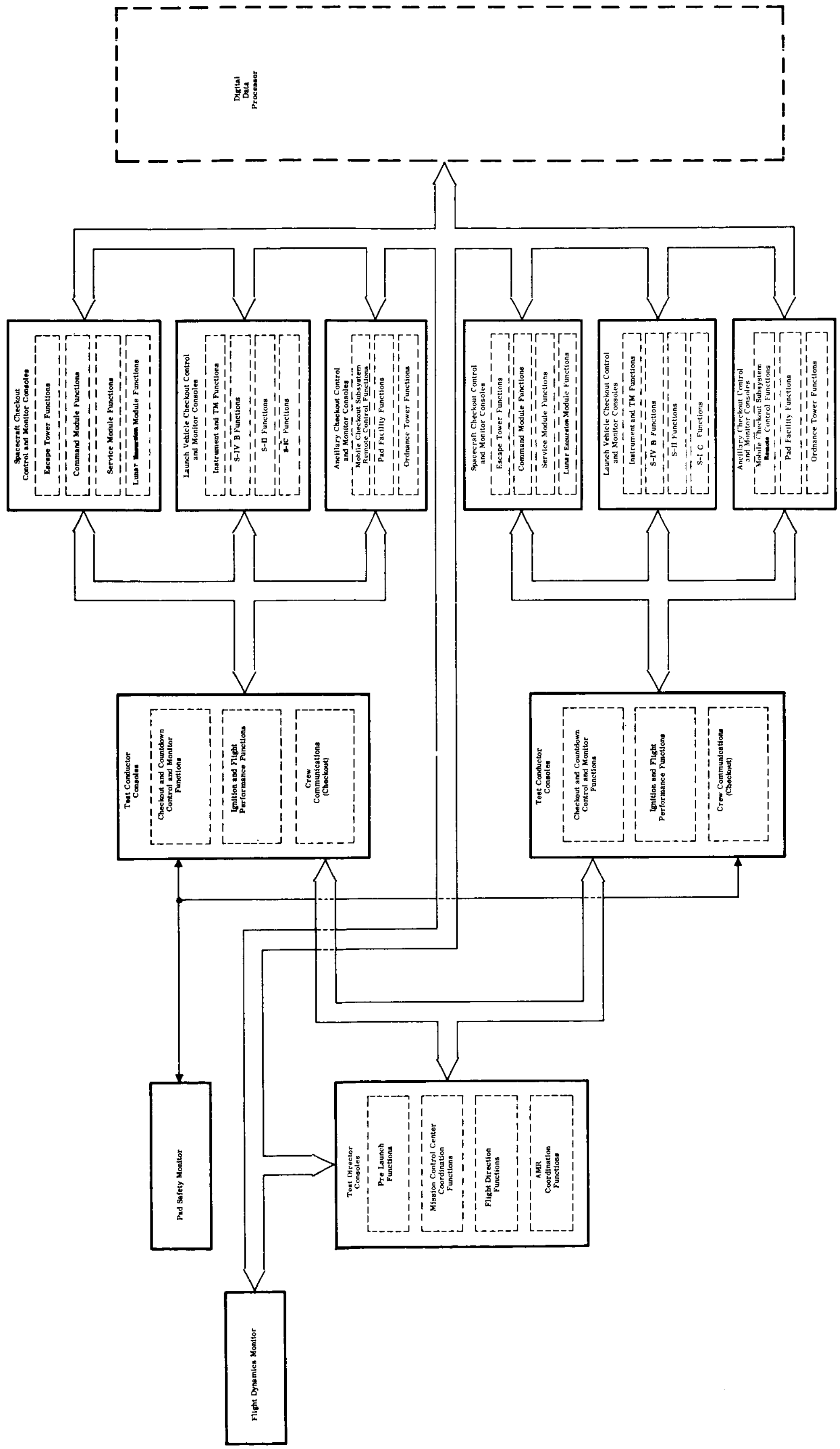


Figure 4-6. Launch Control and Display Subsystem

The two sets of stage/system consoles will contain consoles that are functionally identical with the control and display portions of the mobile checkout subsystem adapter/controllers carried on the transporter-launchers. Physically, these consoles also will be as identical as possible, within the constraints imposed by the differences in their operating environments. Detailed checkout of launch-vehicle and spacecraft functions will be carried out at the stage/system consoles by remote control over the mobile checkout subsystem. Remote control and monitoring of support activities, such as those at the ordnance tower and launch pad, will also be possible from these consoles.

All consoles and associated equipment in the Launch Control Center will be characterized by design with functional modules as building-blocks. The use of modular construction will provide the flexibility and growth capability required to accommodate the frequent launching of vehicles with different flight objectives.

During normal operation of the integrated checkout equipment, a high degree of automation will be provided by the digital data processor. However, each of the console operators will have the capability of manually selecting particular programs, subroutines, and display of results, both qualitative and quantitative, as required to cope with unexpected or extraordinary events. In effect, the operators will be able to use the launch control and display subsystem as an extension of their own capability and ingenuity.

Suitable interlocking of routines and executive programs will establish test priorities to prevent test malfunctions due to conflicting test requests. Additional interlocks will be incorporated to prevent initiation from the Launch Control Center of tests which could be dangerous to transporter-launcher personnel.

During periods when the transporter-launcher is unmanned, all control of the mobile checkout subsystem will revert to the Launch Control Center. Under the direct supervision of the test conductor and test director, mechanical and program operations will be integrated into the countdown plan. Immediately prior to launch, active equipment checkout will reach a minimum. The coordination and operational information displays for the test director will be then of paramount interest.

After lift-off, the test director's console will provide a summary of critical parameters, including telemetry, instrumentation, stage separation and ignition, and flight dynamics. With this information, the test director will be able to evaluate vehicle performance through the initial flight phase.

4.3.2.3.1 Test Director Consoles

The test director consoles will provide the control, monitoring, and communications functions required to:

- Supervise over-all aspects of countdown for two space vehicles.
- Coordinate launch activities with the Mission Control Center and the Atlantic Missile Range.
- Monitor the space-vehicle flight from launch throughout the initial flight phase.
- Recommend termination of the flight or modification of mission objectives if space-vehicle performance is unsatisfactory.

On the basis of preliminary analysis, the following functions have been specified for the test director's console:

- Countdown sequence and checkout summary displays.
- Mission Control Center and Atlantic Missile Range coordination displays.
- Mission Control Center and Atlantic Missile Range communication controls and headsets.
- Flight events performance summary and trajectory indication displays.
- Greenwich mean time and countdown time displays.
- Closed-circuit television monitor.
- Launch enable control.
- Abort command control.

In support of the test director's functions, a flight dynamics monitor will be provided. Information to be displayed on plotting boards will include:

- Flight path angle versus the ratio of inertial velocity to required velocity.
- Altitude versus downrange distance.

- Crossrange deviation versus downrange distance.
- Acceleration and velocity versus elapsed time.
- Latitude and longitude of predicted impact point.

4.3.2.3.2 Test Conductor Consoles

The test conductor's console (see Figure 4-7 for artist's concept) will provide the control, monitoring, and communications functions required to:

- Supervise all countdown operations for one space vehicle.
- Monitor flight performance.
- Provide voice contact with the spacecraft.

Input information to this console will consist, primarily, of summary information from stage/system consoles. The displays and controls on this console will include:

- Spacecraft checkout results.
- Launch-vehicle checkout results.
- Mobile checkout subsystem status.
- Telemetry and instrumentation performance.
- Launch-pad facilities status.
- Ordnance tower status.
- Flight performance.
- Closed-circuit television monitor.
- Closed-circuit television selector.
- Hold or resume count control.
- Initiate firing sequence control.
- Spacecraft communications channel selector.

4.3.2.3.3 Stage/System Consoles

The stage/system consoles will provide the controls and associated displays necessary to perform a detailed and complete checkout of the space vehicle. In addition, support and service functions of the launch pad will be controlled and monitored from these consoles. A listing of the typical functions for the stage/system consoles is given below, with a breakdown of general control and monitoring responsibilities. Additional study is needed to further define these functions.

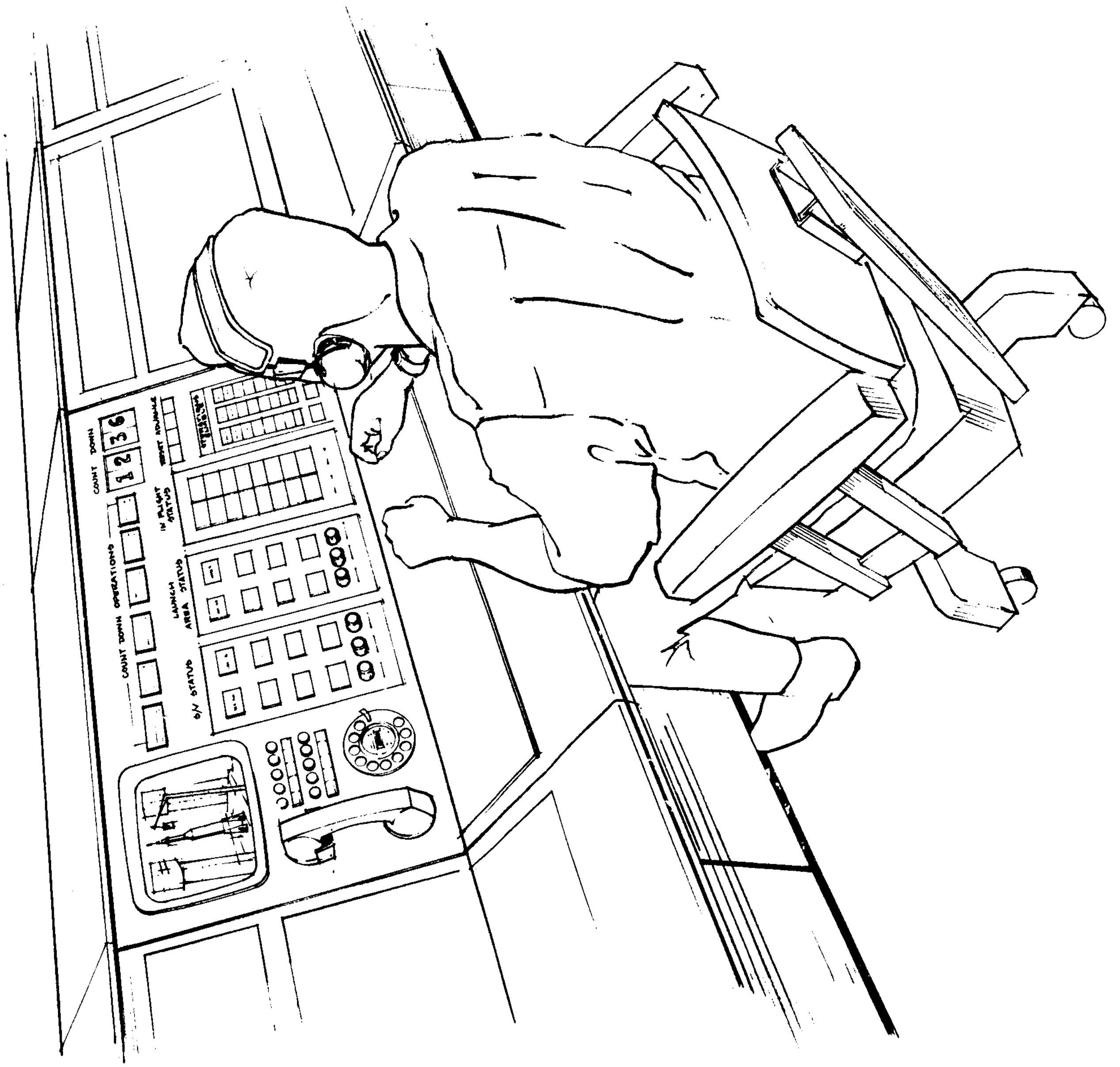


Figure 4-7. Test Conductor's Console

a. Escape Tower:
- Propulsion System.
- Electrical System.
- Command and Jettison Control System.

b. Command Module:
- Environment and Life-Support Systems.
- Attitude, Guidance, Control, and Navigation Systems.
- Electrical System.
- Propulsion System.
- Communications System.

c. Service Module:
- Electrical System.
- Propulsion System.
- Guidance and Control System.

d. Lunar Landing Module:
- Electrical System.
- Propulsion System.
- Guidance and Control System.

e. Launch Vehicle - Each of Three Stages:
- Electrical Systems.
- Propulsion Systems.
- Guidance and Control Systems.
- Staging System.

f. Instrumentation and Telemetry Systems

g. Launch-Pad Facilities:
- Electric Power System
- Fueling facilities.
- Gantry facilities.
- Ground communications.
- Tracking and guidance.
- Emergency facilities.
- Fueling control.

h. Master Mobile Checkout.

4.3.2.4 Central Display and Recording

The central display and recording subsystem will be comprised of space-vehicle status displays, operations status displays, and data tabulation and recording equipment. See the artist's concept, Figure 4-8.

The display boards will provide summary information to key personnel on the status and progress of the countdown operations. These boards will be programmed automatically by the digital data processor to display the latest available data. The space-vehicle status board will be associated with a particular space vehicle, transporter-launcher, and launch pad. The information presented will be checkout oriented and will show the launch-vehicle stage checkout and spacecraft module checkout status. Summary status information on support functions related to the subject space vehicle, transporter-launcher, and launch pad also will be displayed. Significant events will be read out as they occur after preparation by the digital data processor. The operations status board will be oriented toward the current situation and will present information regarding facilities status, Mission Control Center status, Ground Operational Support System status, weather, imposed radio silence, and other factors not connected with checkout that will influence launching.

Supplementing the operations status display will be a large-screen, rear-projected television display. Information from any of the remotely located closed-circuit cameras may be selected at the test conductor's console for viewing on this display. In addition, several stage/system console operators, as well as the test conductors, will be provided with monitors and selection capability for individual viewing.

Recording equipment will be used to record test data during countdown and launch. In addition to this, recordings of all significant audio communications, significant time and events, and specially selected data will be made.

4.3.2.5 Communications

The communications subsystem will be comprised of facilities for communications within the Launch Control Center and with outside agencies, including the Mission Control Center and Atlantic Missile Range Central Control.

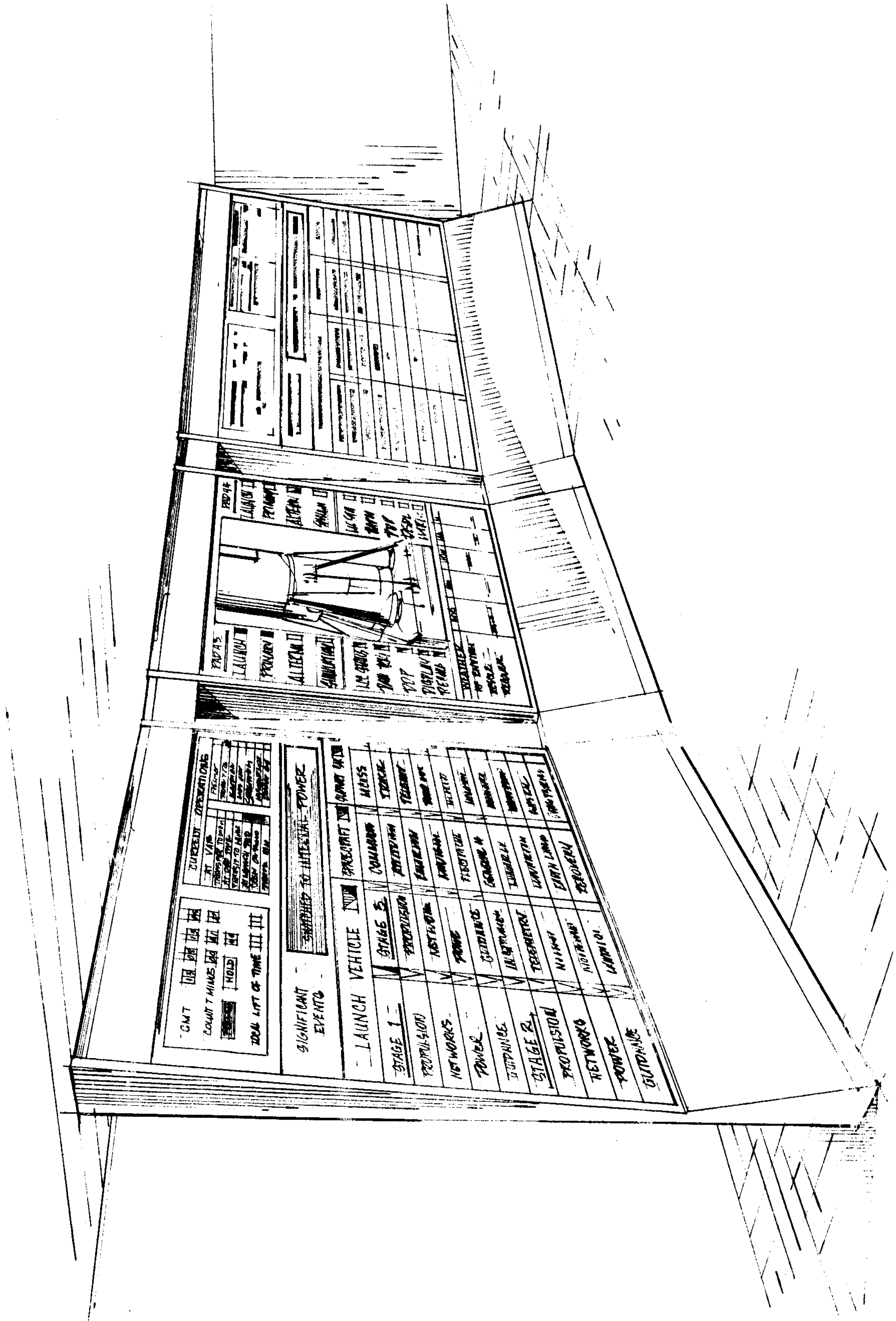


Figure 4-8. Central Status Display

The administrative communications facilities will consist of standard telephone and public address systems. Further study will be required to select a suitable conference system for countdown activities.

A voice system to be used for two-way conversations between the Launch Control Center and the spacecraft will consist of high-frequency (HF) and ultra-high frequency (UHF) systems.

Included in the communications checkout monitor and control equipment will be provision for verifying performance of recovery communications equipment, such as the HF transceiver, c-w SEASAVE beacon, SARAH beacon, and SUPER-SARAH beacon used on the Mercury project.

Also included in the communications subsystem will be television monitoring and control equipment. This equipment will monitor and display the operation of remote equipment. As presently conceived, this equipment will consist of the following:

- Local and remote camera stations with cables and accessory equipment.
- Camera cable patch panels.
- Monitors in the Launch Control Center.
- Video switching and synchronization units.
- Camera control panels, and a master monitor and control console.

High-quality cameras, with remote control of electrical functions and zoom lenses, will be located throughout the launch complex. Remote controls for the cameras will be located directly under each monitor, as well as at the master monitor and control console.

The master monitor and control console will be the central station for all television equipment. The console operator will be able to train the cameras on desired subjects and switch any monitor to any camera. The console operator also will be able to transfer control of the camera lenses and azimuth/elevation controls to the stage/system engineers, so that they may monitor such functions as fueling and removal of umbilicals and service ladders.

4.3.2.6 Checkout Data Synthesizer

The primary function of the checkout data synthesizer subsystem will be to provide a means of simulating Launch Control Center inputs and terminating outputs for self-check verification. The checkout data synthesizer essentially will consist of a video and RF generator, signal conditioner, video analyzer, and control console. Under control of the digital data processor, the video and RF generator will supply simulated signals to the data link inputs. The simulated signals, compared by the digital data processor with the equipment responses, will permit a closed-loop functional check on the Launch Control Center equipment. To aid in the isolation of equipment malfunctions, the signal conditioner and video analyzer will allow digitizing either static or dynamic signals in the data translator subsystem.

4.3.2.7 Launch Operations Control Center

The Launch Operations Control Center, as conceived, will be essentially a tool for use by launch operations management personnel in planning, scheduling, and controlling the launch operations task. Physically, the Launch Operations Control Center will be a display area within the Launch Control Center facility that will aid in the management of launch operations. As discussed above under Launch Control Center functional requirements, the function of this display area will be to provide a detailed definition of the sequence and interdependencies of the tasks and required events comprising each launch operation cycle. This definition must include detailed schedule and status information.

The Launch Operations Control Center displays will describe graphically each launch operation cycle in the following terms:

- Identification of each space-vehicle stage required for a particular flight.
- Schedules for stage arrival at the Vertical Assembly Building, and their pre-arrival status.
- Definition and status of all major Vertical Assembly Building assembly and checkout operations.
- Definition and status of important postassembly activities related to space-vehicle transportation to the launch area, ordnance tower functions, and launch area activities.
- Availability status of all facilities and support equipment critical to the launch operation cycle.

A PERT diagram or equivalent flow chart would constitute an excellent format for the detailed displays required. The dependencies and interrelationships of activities would be identified on such a display along with critical schedule paths and the completion status of each event.

In addition to the detailed PERT-type display, two other display types are deemed necessary. The first is a display which would summarize the detailed PERT-type display. A bar-chart format would be suitable for this display.

The second display type would present status information associated with the facilities and support equipment used in a launch operation cycle. Information would be provided with regard to the availability status of:

- Vertical Assembly Building facilities and equipment.
- Ordnance tower facilities and equipment.
- Transporter-launcher and built-in support equipment.
- Launch-area facilities and equipment.
- Communications networks.
- Launch Control Center operational equipment.

Status information would be presented in terms of go, no-go data with the no-go status further qualified as to the nature of the problem and the predicted time required to achieve a go condition.

Further study is required to determine the optimum means of mechanizing the Launch Operations Center display devices. Mechanization possibilities range from simple, manually prepared and updated charts to fully automated displays programmed in real time from the Launch Control Center digital data processor. It appears that fully automated displays would be unnecessary and undesirably costly and complex. Conversely, simple chart displays would have the disadvantage of being less than optimum from a viewing standpoint and also would be relatively difficult to keep current.

A display technique under consideration for the Launch Operations Control Center would incorporate the superposition of photographic-slide imagery. Using this method, alpha-numeric data and complex symbology would be permanently stored on a 35-mm photographic slide and projected on a screen. Current status information in the form of colored lines and simple geometric shapes would be projected simultaneously upon the above image. These lines and symbols of temporary data would be generated by a slide-scribing mechanism (slide writer) programmed with the latest information. Updating of status information would be performed by slide writers generating temporary data slides. Figure 4-9 is a block diagram of this system. An artist's concept, showing the Launch Operations Control Center and associated displays, is shown in Figure 4-10.

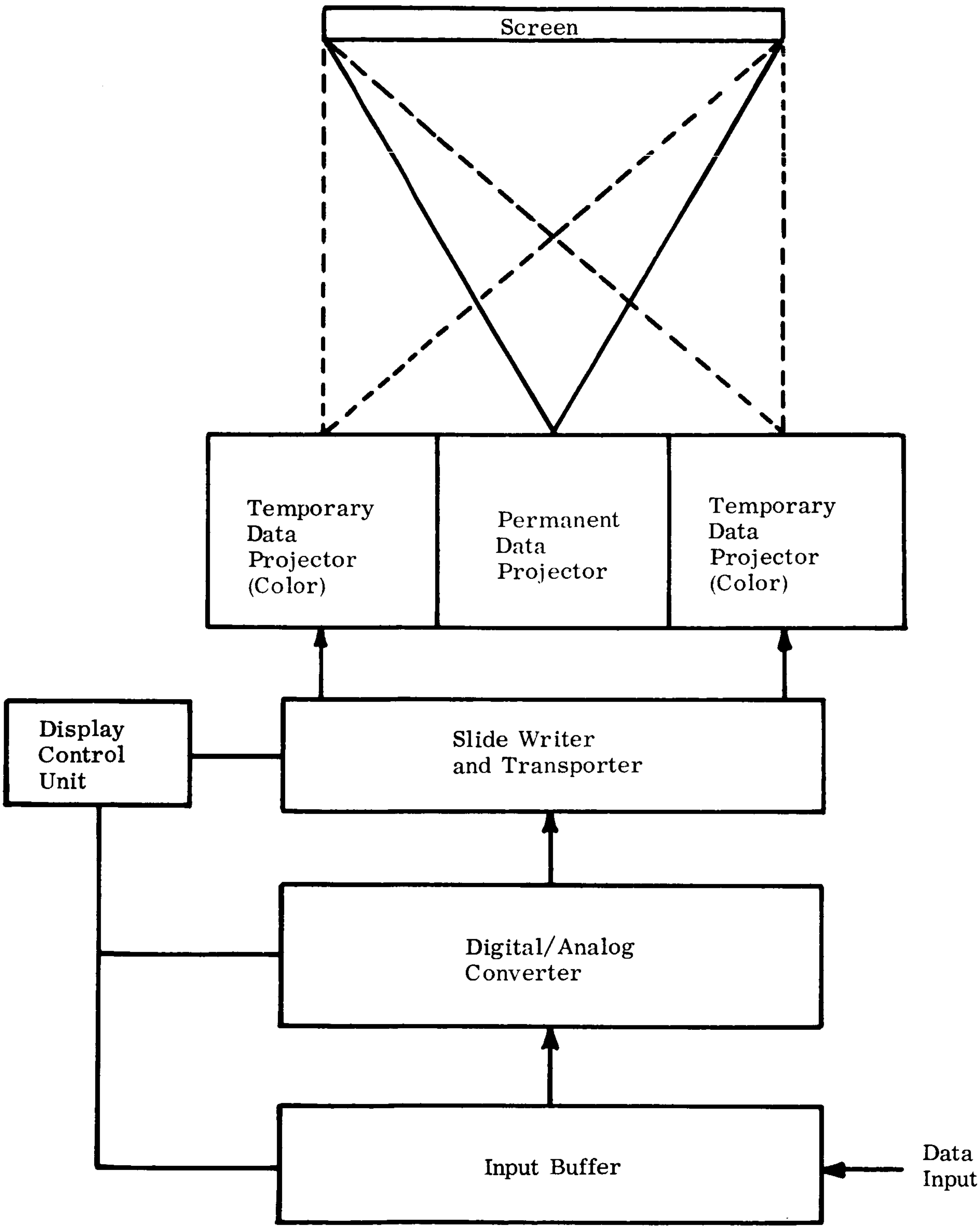


Figure 4-9. Launch Operations Control Center Projection Technique

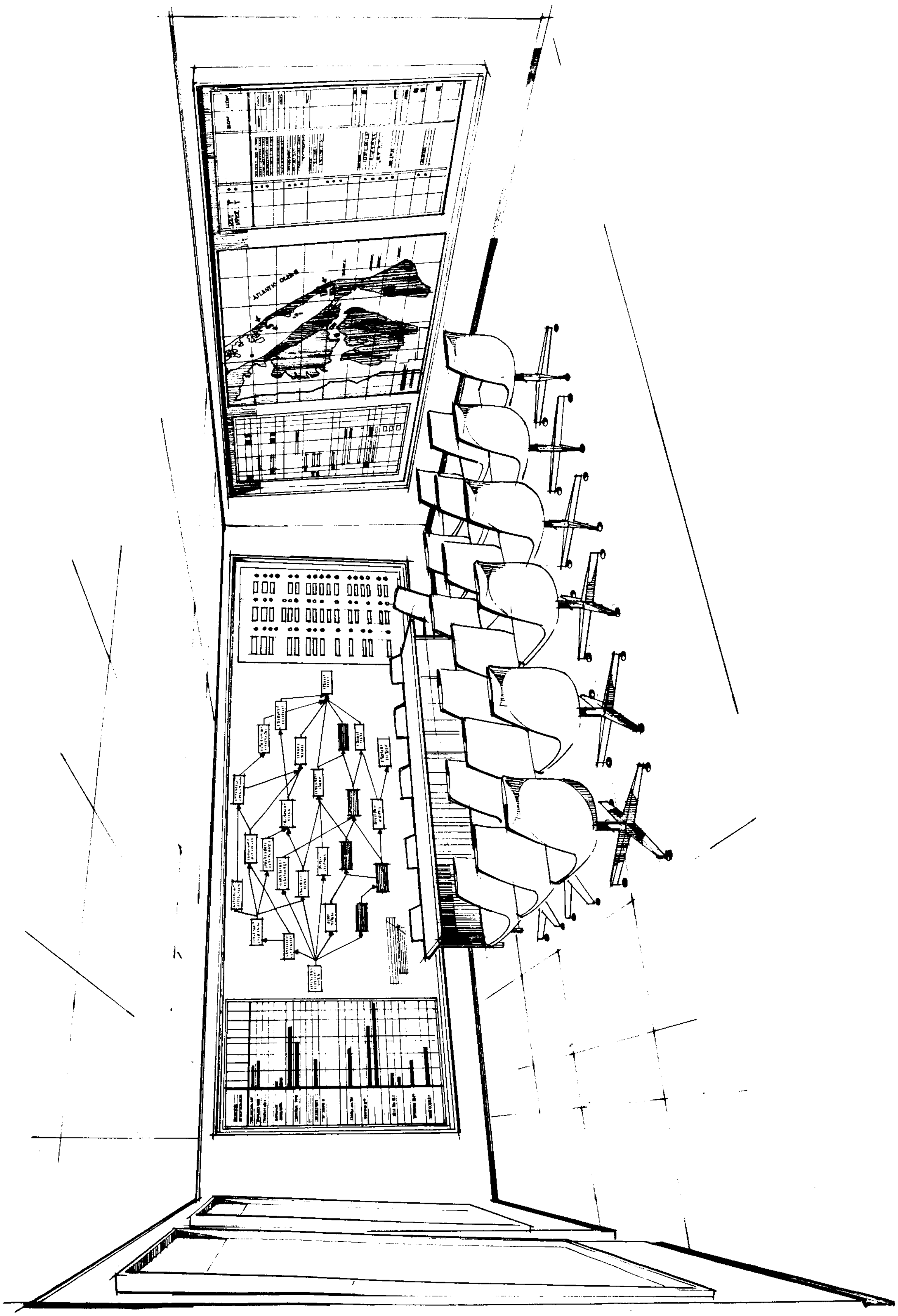


Figure 4-10. Launch Operations Control Center

SECTION 5
TECHNICAL DEVELOPMENT PLAN

5.1 INTEGRATED CHECKOUT SYSTEM IMPLEMENTATION PLAN

5.1.1 INTRODUCTION

The development plan for the Integrated Checkout System provides for constraints due to firing schedules, vehicle configuration schedules, and launch facilities and their schedules. This section presents suggested checkout equipment development and delivery schedules based on currently published vehicle schedules. These schedules are capable of adjustment as program needs deem necessary.

A series of implementation flow charts are also presented, detailing the implementation activities and showing the interrelationships of these activities. The flow charts also show, where possible, information or liaison needed by General Electric to perform the implementation and to identify the implementation end items and their influence on NASA facilities and the prime equipment suppliers.

5.1.2 IMPLEMENTATION PLAN SCHEDULE

5.1.2.1 General

The implementation plan schedule for the Integrated Checkout System, keyed to event milestones of the Apollo Program, is illustrated in Figure 5-1.

The implementation plan enables orderly growth of the system and provides for maturing of equipments prior to support of manned missions through a modular system design. The implementation plan provides support of the test operations of the Apollo program through the C-1, C-1B, and C-5 program phases to the goal: manned lunar flight.

Flight schedules and mission configurations are based on the Manned Spacecraft Center publication, Apollo Program Schedules, dated 16 March 1962, and Marshall Space Flight Center publication, Consolidated Program Schedules, dated 18 March 1962. The facilities schedules are taken from the publication C-5 Facilities Construction Schedule, dated 31 May 1962. The development and equipment delivery schedules, as presented, are related to these schedules; necessary adjustments in equipment deliveries can be made responsive to NASA program modifications and/or schedule changes.

5.1.2.2 Program Implementation Schedule

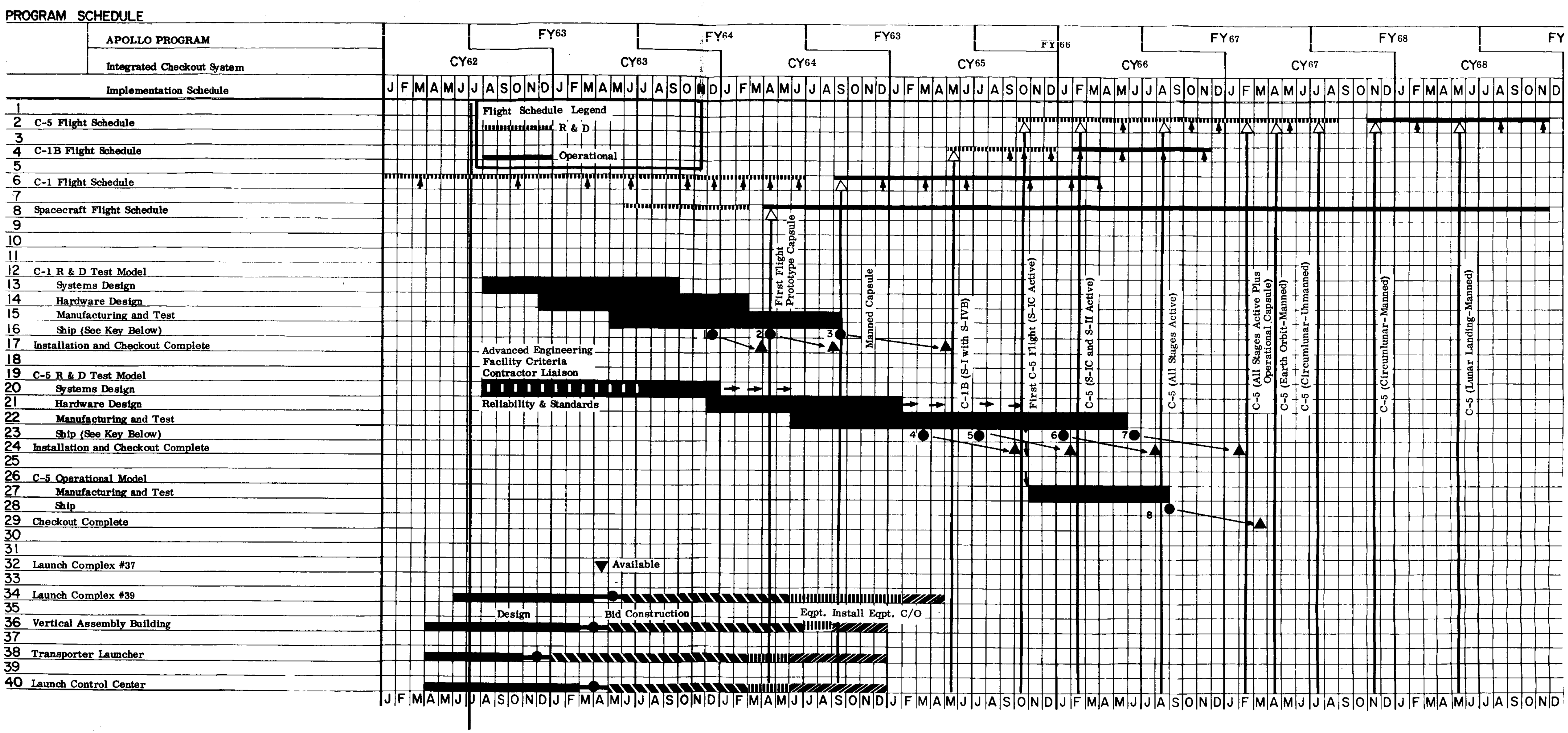
Figure 5-2 identifies the integrated checkout equipment shipped to support the C-1 program in tests on the prototype space capsule and to support the C-1B mission requirements.

The first equipment will be shipped for checkout of the first prototype capsule test. This equipment will be installed in a blockhouse at either Pad 34 or 37, as the facilities programming schedule will indicate. The capability of this equipment will be expanded as flight experience indicates, and to accommodate manned capsule tests. This checkout equipment will be expanded also to accommodate the S-IVB program.

The interface between the vehicle and the integrated checkout equipment will lie in the adaptors. For this reason, adaptor deliveries subsequent to the initial one for each item will consist mainly of vehicle-supplied equipment and appropriate refurbishing equipments for umbilical tower adaptor elements.

Should program requirements dictate a need to assemble a C-1B at the Vertical Assembly Building, and subsequent launch from Complex 39, it is planned that AMR checkout equipment be relocated or that the identical equipment at the contractor's facility would be used.

Figure 5-3 identifies the integrated checkout equipment shipped to support the C-5 mission requirements. The first equipments will be shipped in March 1965 for installation in the activated portions of the Vertical Assembly Building, the activated transporter-launchers, the Launch Control Center, the ordnance tower, and the activated launch pads. The equipment will be supplied in accordance with the detailed facilities schedules supplied by NASA's Launch Operations Center and are intended to be available for the first C-5 vehicle.



Key for Shipping Schedule

1. Ship ICO Eqpt. for unmanned S/C to Cape for installation in Blockhouse. (One set also to Engineering test Bed.)
2. Ship ICO Modification Components (modify for manned S/C).
3. Ship ICO Modification Components for SIVB (C-1B Program).
4. Ship ICO Eqpt. for installation in VAB, LCC and Transporter Launchers (2) to accommodate S-IC stage tests.
5. Ship ICO Modification Components for S-II tests.
6. Ship ICO Modification Components for SIVB and unmanned S/C tests.
7. Ship ICO Modification Components for C-5 manned flights.
8. Ship ICO operational equipments (all transporter-launchers, all VAB Bays, Complete LCC.

Figure 5-1. Integrated Checkout System Implementation Schedule

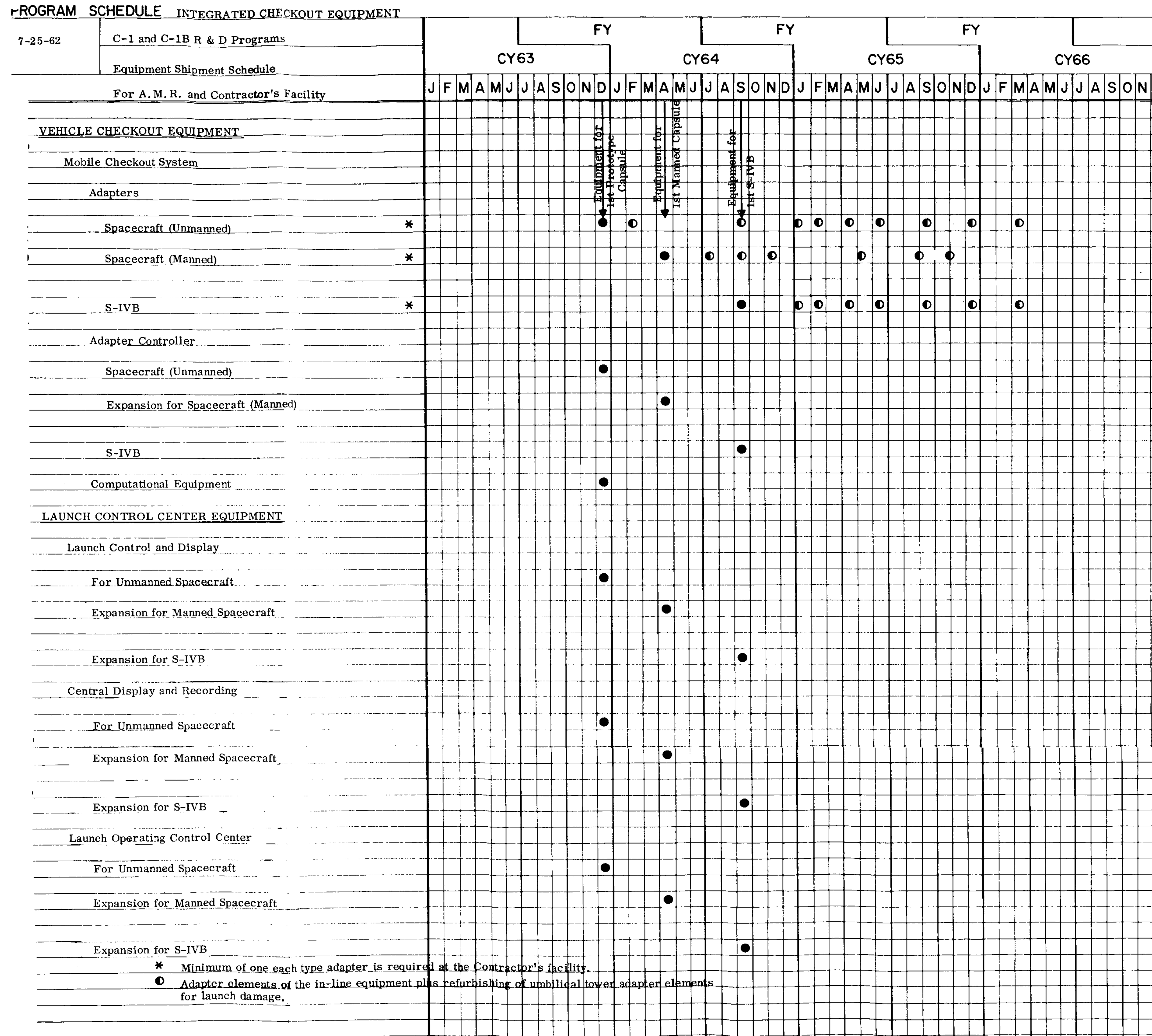


Figure 5-2. C-1 R and D Program Equipment Shipment Schedule

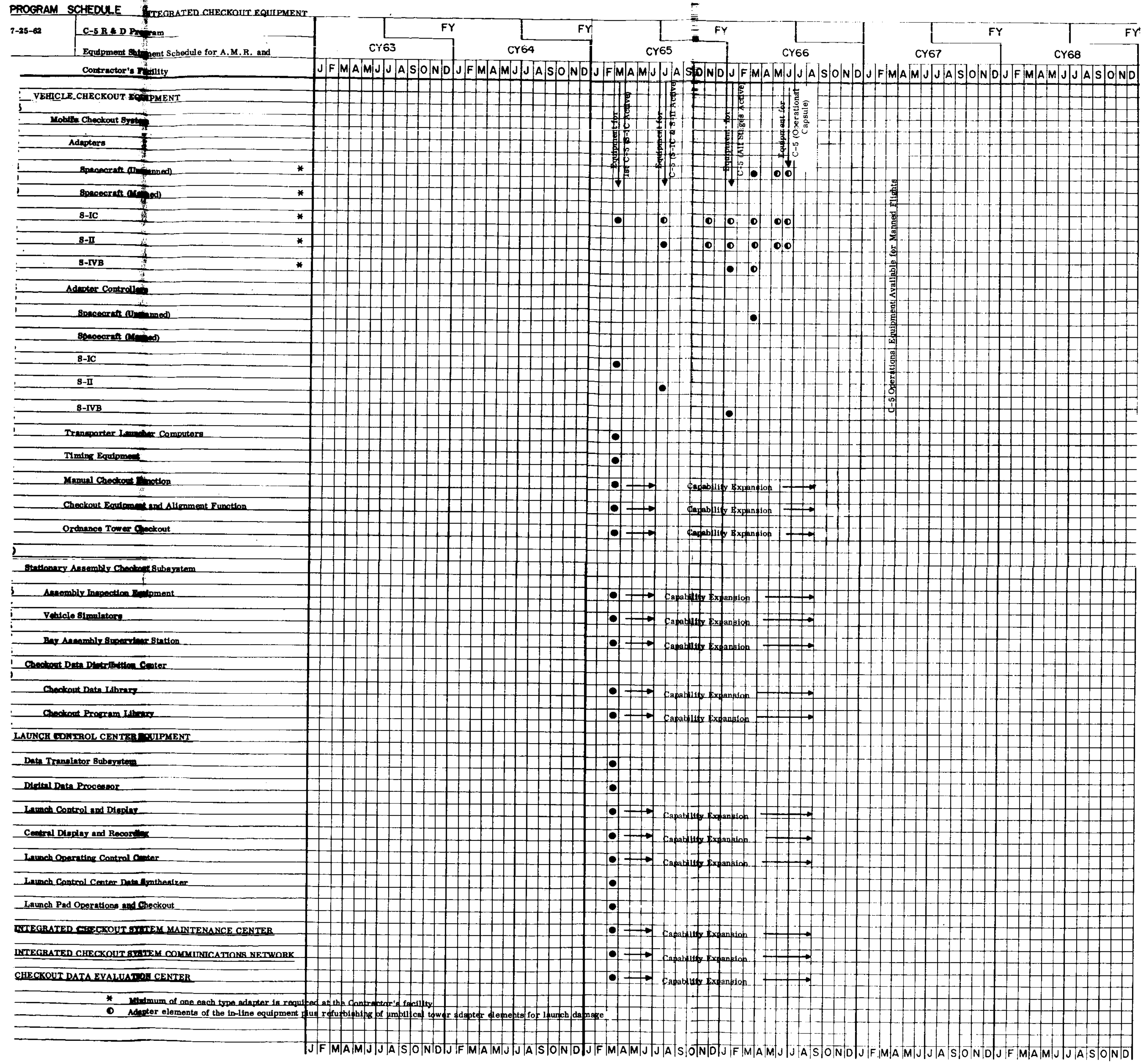


Figure 5-3. C-5 R and D Program Equipment Shipment Schedule

As is indicated by the schedule, equipment deliveries will be scheduled by the program needs. The equipment will be matured and appropriately expanded, to be capable of support of the complete C-5 vehicle.

Though not explicitly indicated on the schedule, this equipment would be replaced in 1966 by an operational version which will represent a fully matured Integrated Checkout System, capable of supporting the Manned Lunar Program using the C-5 vehicle.

It is planned that this equipment will also be capable of supporting the RIFT Program by the addition of appropriate adaptor and adaptor-controller elements and the addition of appropriate Launch Control Center elements.

5.1.3 IMPLEMENTATION PLAN FLOW CHARTS

5.1.3.1 Over-all C-1 and C-5 Programs

Figure 5-4 presents the major steps in the development activities associated with the development of the Integrated Checkout System. It also presents the current plan for transfer of operational experience from the C-1 program to the C-5 program, and the manner in which the experience of both programs is brought to bear on the C-5 operational equipment program.

The utilization by the C-5 R and D system of the functional design, test routines, and programs for the manned and unmanned spacecraft and for the S-IVB stage from the C-1 program is indicated. The detailed designs evolved in the C-5 R and D program and the appropriate test programs and routines from the C-5 test-bed program, are shown utilized in the corresponding designs and test programs for the C-5 operational program. The figure also shows the integration of the C-5 R and D Integrated Checkout System with the operational subsystems in the operational program.

The test-bed program would continue in the operational phase to provide updated test routines and programs necessary for support of the lunar program. The test-bed program would be updated to prepare for the RIFT firings, for the Nova program, or other programs as is indicated by subsequent NASA plans and schedules.

5.1.3.2 C-1 R and D Program

Figure 5-5 presents the major elements of activity during the C-1 R and D program. The presentation uses a flow-type format to more clearly illustrate the dependency relationships within the plan.

The initial activity indicated as "Preliminary Design Phase" is discussed in more detail in Section 5.1.3.4. The main outputs pertinent to the C-1 program will be the Vehicle Checkout System specifications and block diagrams, the C-1 Launch Control Center specifications and block diagrams, the test-bed equipment specifications and block diagrams, and the facilities requirements.

5.1.3.2.1 Vehicle Checkout System

The equipment supplied for the C-1 program will be designed for blockhouse environment, and, since the vehicle will be erected on the launch pad, only the transporter-launcher computer, the appropriate adaptors, and adaptor-controllers will be provided.

The first equipments to be supplied will be for use on the unmanned prototype space capsule. In addition to supplying adaptor controllers to the test bed and to the blockhouse, an adaptor-controller will be supplied to the spacecraft contractor for use in his facility and for Manned Spacecraft Center/Preflight Operations Division use in the hangar areas at AMR. Updated equipments will be made available as the program progresses.

5.1.3.2.2 Launch Control System

It is not envisioned that all of the Launch Control Center equipments need be provided for support of the C-1 program from the blockhouse. Thus, only those Launch Control Center elements concerned with launch control, the spacecraft, and S-IVB will be provided.

5.1.3.2.3 Test-Bed Program

For the purpose of performing system tests, training, and for use as a design tool, a test-bed program will be undertaken by the contractor. This test bed is envisioned as containing a complete Integrated Checkout System for use in conjunction with a vehicle simulator.

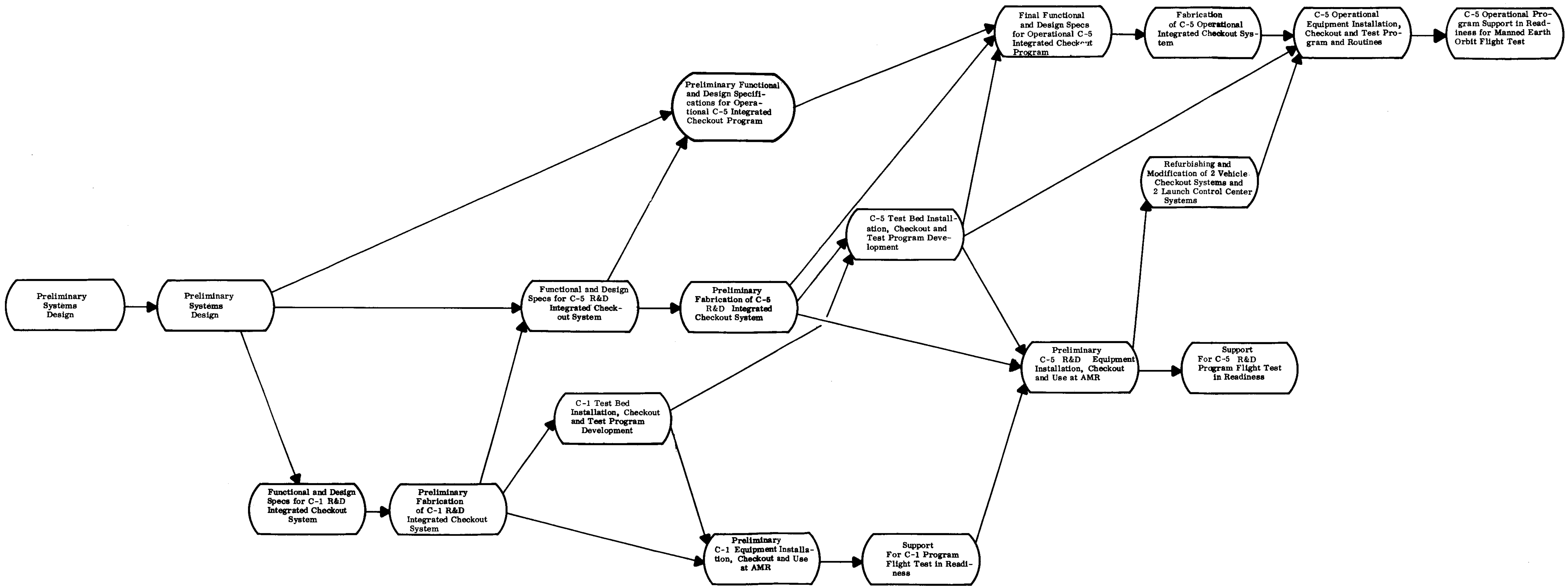


Figure 5-4. Implementation Plan for Integrated System Support of Over-all C-1 and C-5 Programs

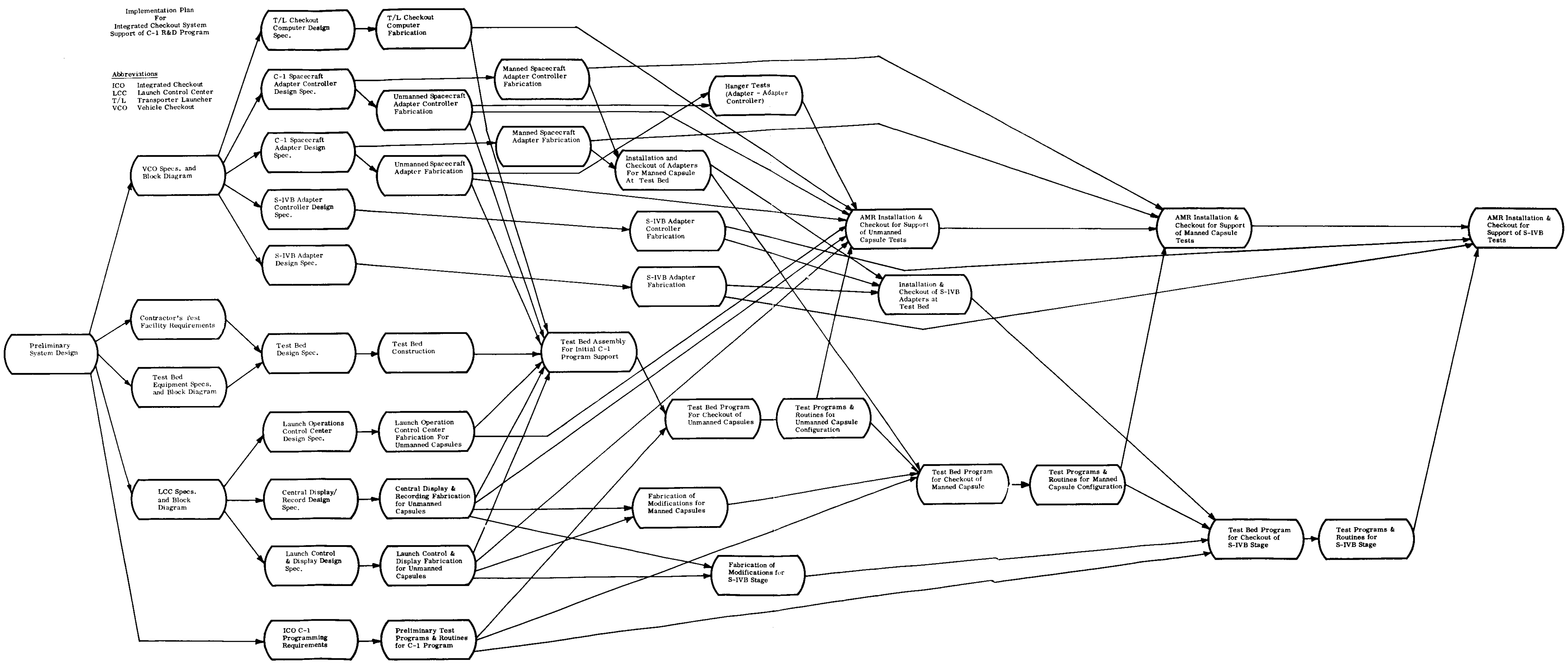


Figure 5-5. Implementation Plan for Integrated Checkout System Support of the C-1 R and D Program

System tests would be performed at this facility to develop and perfect test routines and to give final tests to the developed checkout programs prior to shipping to AMR.

It would be a convenient tool for training of NASA and prime-equipment contractor personnel in the use of the Integrated Checkout System without tying up the AMR operational equipments.

Prototype developments may be incorporated in the test bed for design and operational evaluation. This would insure compatibility of equipments supplied later in the program with those first supplied and would minimize time required for AMR installation and checkout.

5.1.3.3 C-5 R and D Program

Figure 5-6 presents the major elements of activity in development of the C-5 R and D checkout equipments.

As may be seen, the starting point is again the preliminary design phase. This time, however, it is planned that a complete Integrated Checkout System be provided for installation at Complex 39. The flow chart shows the addition of capability as it is required in support of the C-5 development program.

The experience gained in the C-1 program is brought directly to bear on the R and D operational program and will greatly enhance the maturing of the equipments and operations during this phase.

As in the C-1 program, a test-bed program will be undertaken. In many respects, the C-5 R and D test-bed program will have parallel objectives to the C-1 R and D program - the equipments and operations will necessarily be quite different, however.

5.1.3.4 Preliminary Design Phase

Figure 5-7 presents the activities and relationships in the preliminary design phase. In order that the integrated checkout equipments developed for the C-1 and C-5 programs may have a common design base, no distinction is made between them in preliminary design.

The starting point for preliminary design activities will be the Integrated Checkout System functional specifications developed in the Phase I study.

An effective design effort will require liaison with the stage contractors and the NASA centers as early as possible.

Certain of the preliminary design activities may be started almost at once and without extensive NASA or stage contractor liaison at the outset. These are activities such as reliability and standards, human engineering, and preliminary system test plan for use of the test bed. These activities are discussed more fully in the subsequent sections.

Those liaison-oriented activities will be briefly discussed in the following paragraphs.

5.1.3.4.1 Stage Simulator Specifications

Each of the stage contractors would provide information for the simulation of their stages in the space-vehicle simulator to be installed in the Vertical Assembly Building and at the contractor's test bed.

5.1.3.4.2 Subsystem versus Mission Schedule Matrix

This would provide a matrix showing, for every scheduled firing, the subsystems in every stage. This is clearly not a static matrix, and the activity would be continued throughout the program.

The information in conjunction with space-vehicle interface configurations would be used in programming or appropriately modifying the Integrated Checkout System for every vehicle.

5.1.3.4.3 Stage Checkout Sequences and Procedures

This would present the sequences and procedures pertinent to the checkout of the entire stage. It would tell the order in which subsystems should be tested, the set-up conditions necessary for each subsystem test, and would identify stage simulator requirements.

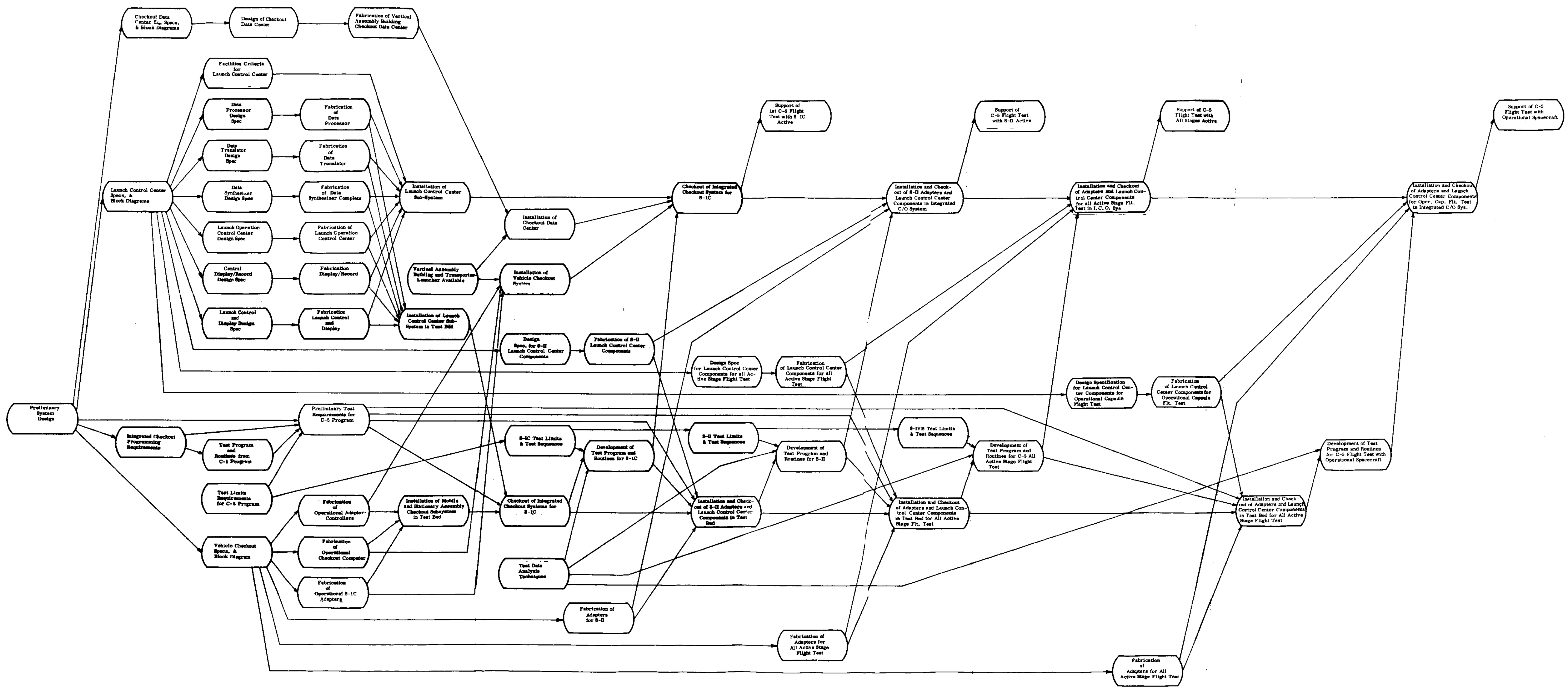


Figure 5-6. Implementation Plan for Integrated Checkout System of the C-5 R and D Program

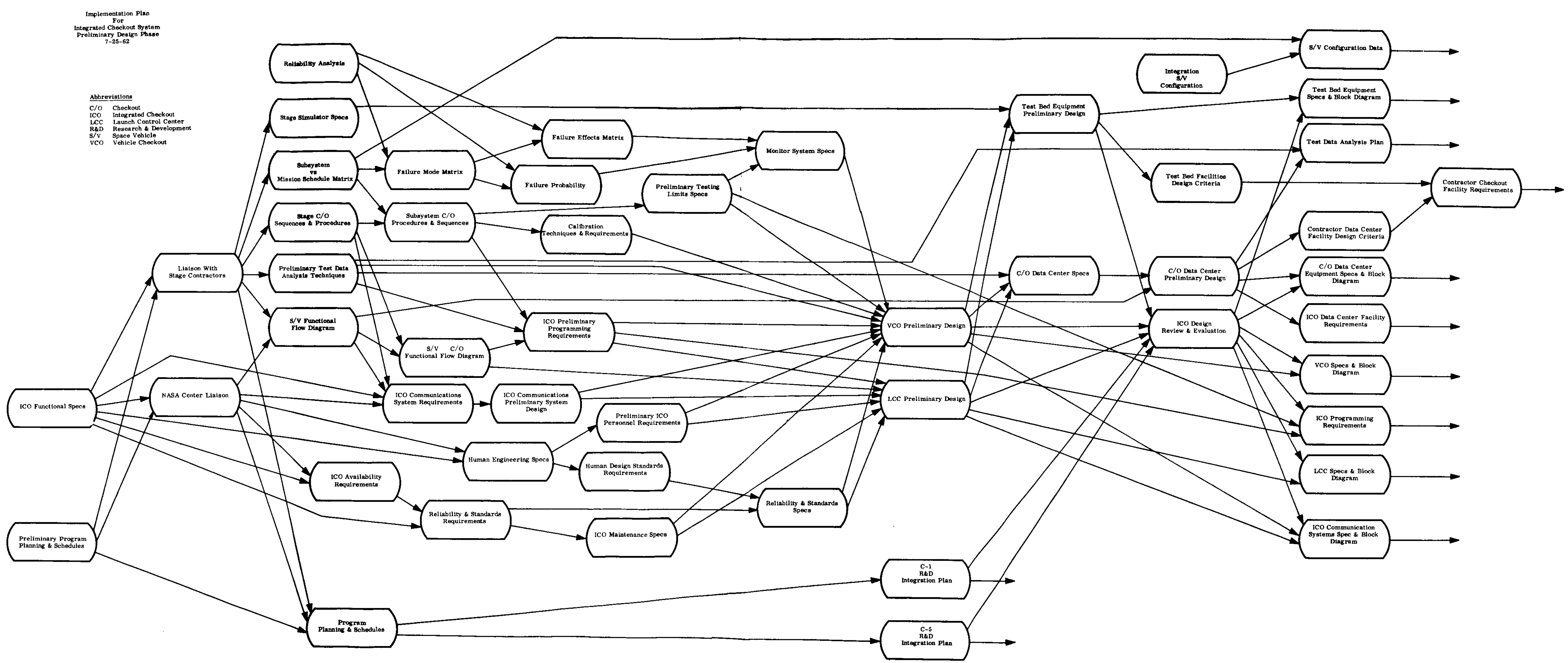


Figure 5-7. Implementation Plan for Integrated Checkout System Preliminary Design Phase

5.1.3.4.4 Space-Vehicle Functional Flow Diagram

This is a flow-type diagram which presents the detailed sequence of activities for each stage from the manufacturer's facility through final injection into orbit. This would include static firings, qualification tests, transportation, etc., and would give nominal times required for each activity with variance (1 σ) on these nominal times.

5.1.3.4.5 Preliminary Test Data Analysis Techniques

A review of the test data analysis techniques used by the various stage contractors in the evaluation of their test data. This review is intended to provide insight into the possible incorporation of some of these techniques into the Integrated Checkout System. This would further provide guidelines in the use of test data and would lead to selection of pertinent test data for compression and availability in integrated checkout for historical reference.

5.1.3.4.6 Subsystem Checkout Procedures and Sequences

This would be the detailed information on the procedures and sequences used in checkout of each subsystem in the stage.

5.1.3.4.7 Space-Vehicle Checkout Functional Flow Diagram

This is again a flow diagram which extracts from the space-vehicle flow diagram those activities pertinent to checkout. Once more, nominal times for each activity and the variance (1 σ) on this nominal time should be indicated.

5.1.3.4.8 ICO Communications System Requirements

In conjunction with the Launch Operations Center and the knowledge of the checkout functional specifications and operations requirements, the ICO communications system requirements will be developed.

5.1.3.4.9 ICO Availability Requirements

This analysis will tell us the mean time to failure required of the Integrated Checkout System. It is recognized that not all of the elements of the Integrated Checkout System will have the same mean time to failure requirement, thus each element will be specified to have some minimum mean time to failure. In conjunction with this, the required level of reliability for error-free operation during use must be determined and made known as a function of the Integrated Checkout System element to the Reliability and Standards Group.

5.2 RELIABILITY AND DESIGN STANDARDS

5.2.1 INTRODUCTION

The Integrated Checkout System obviously must have high reliability. The required reliability will be established by an appropriate balance of design reliability and an equipment maintenance program based on an analysis of availability requirements.

Design reliability may be provided in three ways:

- Component evaluation and selection.
- Design concepts - the appropriate balance of selected components and element redundancy to achieve a desired system reliability.
- Standard design practices - the use of approved component and circuit standards in conjunction with engineering design review practices.

5.2.2 DESIGN RELIABILITY

5.2.2.1 Design Standards

Design standards will be established in the early stages of the design phase. The method of communicating these standards to design personnel will be to establish an Apollo Checkout System Data Book. This book will contain standards such as approved parts and procedures established for the system.

5.2.2.2 Design Review

The design review will provide an extensive evaluation of all electrical and mechanical aspects of the design.

Experienced design and reliability personnel will make up the design review teams. The detailed planning and scheduling of these reviews will be made part of program planning.

5.2.2.3 Component Parts Control

Component standards based on military standards, preferred parts lists, and test results will be established, using company standards as a base. To accomplish this function effectively, reliability personnel will utilize the services of component-parts specialists. Approved parts will be listed in the Apollo Checkout System Data Book. Figure 5-8 is included as an illustration of a typical parts list taken from a previous project data book. Application information is available as well as approved parts listings.

5.2.2.4 Prediction

Reliability predictions made as the program develops will provide a continuing estimate of Integrated Checkout System reliability.

5.2.3 MANUFACTURING RELIABILITY

The manufacturing quality control organization will be responsible for the establishment of procedures to insure that the design reliability previously established is not degraded.

Reliability and quality control personnel will review and establish procedures for the Integrated Checkout System to insure that factory-failure information is available for reliability measurement, failure analysis, and correction.

A detailed explanation of factory-failure reporting and failure-analysis procedures will be included in Revision I of the Implementation Plan.

5.2.4 FIELD RELIABILITY

In addition to establishing factory-failure control systems, the General Electric Company will establish a field-failure reporting system in accordance with NASA requirements.

5.2.5 RELIABILITY PROGRAM MANAGEMENT

The first major task will be the establishment of a detailed program plan. It is anticipated that the reliability program plan will consist of the following:

a. Design Phase

- Establishment of standards.
- Design review.
- Prediction.

b. Manufacturing Phase

- Review manufacturing and quality procedures.
- Establish failure reporting procedures.

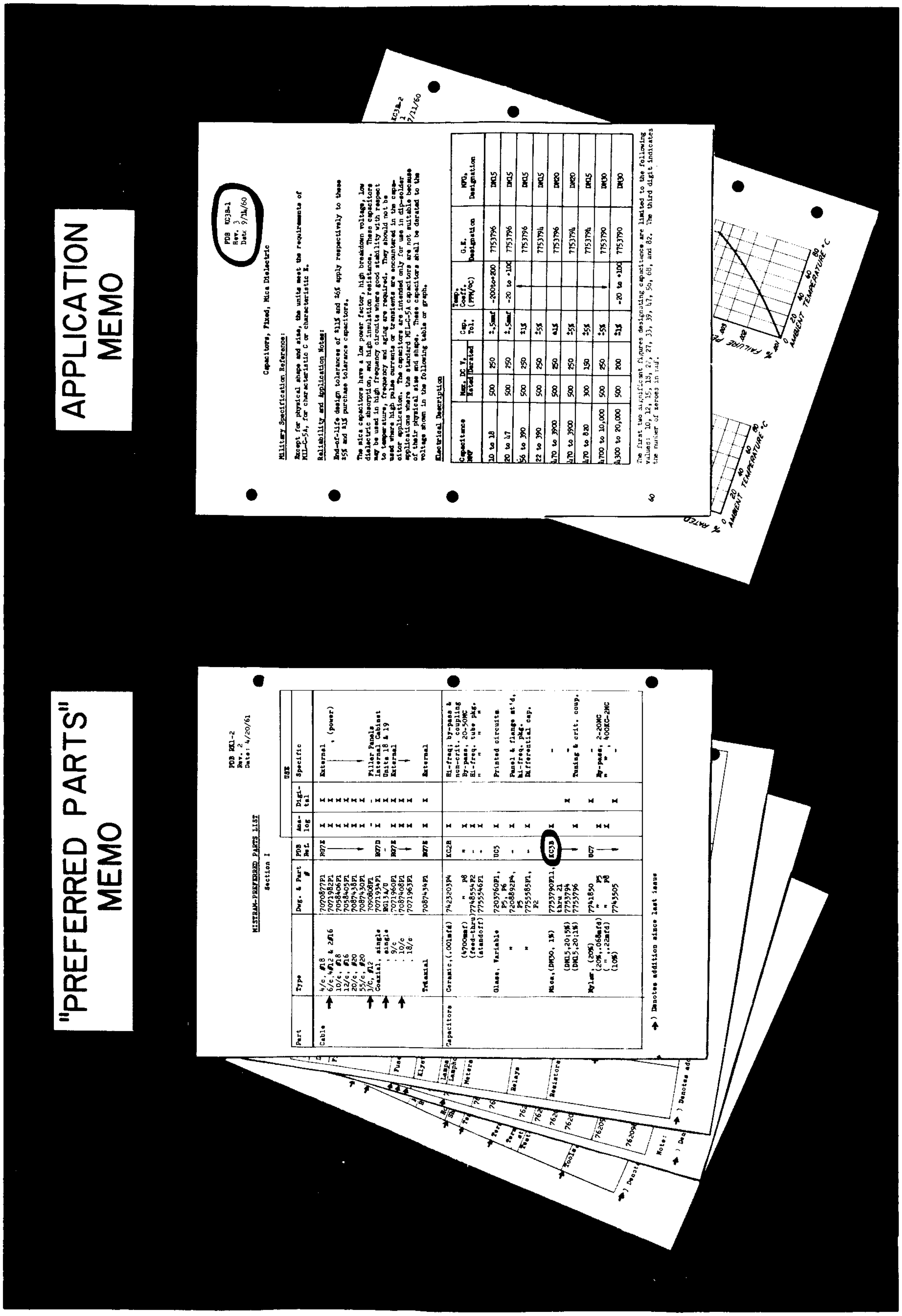


Figure 5-8. Preferred Parts Memo and Application Memo

c. Reports

- Reliability program plan.
- Periodic reliability report, containing:
  1. General progress.
  2. Current reliability estimate.
  3. Malfunction analysis reports.
  4. Reliability improvement proposal.
  5. Equipment operational-time record.

5.2.6 FACILITIES

Reliability engineering personnel have available the service of four well-equipped laboratories.

The Reliability Engineering Laboratory is equipped to analyze the performance of component parts and circuits, study degradation, and investigate design parameters by means of circuit simulation, life testing, and aging. The effects of environments, such as extremes in temperature and humidity, are combined with life testing to establish failure modes, drift rates, and deratings necessary to assure reliable performance.

The Standardizing and Calibration Laboratory maintains facilities for periodic calibration of all electrical instruments and measuring devices.

The Standard Components Laboratory contains a complete set of environmental test equipment to certify any component against military specifications. The facilities provide for salt spray, humidity, vibration, and shock testing.

The Materials and Processes Laboratory contains chemical and physical analysis facilities. The equipment includes such items as an emission and infrared spectrograph, a mass spectrometer, and X-ray equipment. Physical test facilities are available to test under pressures up to 20 thousand psi. This laboratory is equipped to provide analysis of any problem relating to corrosion, chemical contamination, or similar effects.

5.3 SYSTEMS TEST PLAN

5.3.1 INTRODUCTION

To verify the equipment integrity, to establish sound checkout procedures and programs, and to enable the Integrated Checkout System to be used with a high degree of confidence, a system test program will be undertaken. Central to this test program will be the development and operation of an Integrated Checkout System test facility.

The test program will provide a method for evaluation of the checkout equipment, development of checkout procedures and programs, checkout equipment operator training, and design evaluation of alternate schemes.

The subsequent discussion will present some of the considerations which enter into the development of the plan.

5.3.2 FACTORY AND FIELD TEST PROGRAM

The factory test program will provide a rigidly controlled in-house and subcontracted verification of design requirements and specifications. Design requirements and specifications will be reviewed continually and updated based on the analysis of test data operational considerations, latest mission requirements, and space-vehicle configuration. Factory verification of the system checkout equipment will be performed through the use of a space-vehicle simulator. Operational and equipment programming procedures will be prepared during this period.

The field test program will provide an operational performance verification of the checkout system and associated checkout and launch functions under actual environmental conditions. Facility and communication interfaces will be verified, and any modifications to the checkout system resulting from test data analysis will be reflected into the design requirements and specifications, via the proper configuration control procedures.

5.4 PERSONNEL REQUIREMENTS

5.4.1 INTRODUCTION

In the development of systems in which the consequences of human error may be extremely great, it is necessary that the system design and the design of all its supportive elements minimize the probability of human error by explicity taking account of human performance characteristics and by providing a high degree of compatibility among these elements.

Therefore a program of human-factors work will be established which includes human engineering in the design of the Integrated Checkout System and the development of manning structures, training programs, and technical documentation. This human-factors program will be performed in parallel with the over-all engineering analysis and design program and will be managed as an integral effort to assure the timely availability of trained personnel and technical documentation. At the same time, they will also attempt to assure that NASA personnel policies and standard operational practices are reflected in the system concept.

5.4.2 HUMAN ENGINEERING

To assure that human capabilities are properly reflected in the system design, human-factors specialists will participate in all phases of the engineering program. In the early part of the program, they will participate in the identification and allocation of system functions. In later phases of the program, they will make design recommendations regarding particular displays, controls, and workspace layouts.

When the human functions have been identified, they will be analyzed to determine the tasks to be performed within each function. This task information can then be used to identify the actions that are expected of the operator and the information required to initiate and direct the action.

After defining the human functions, their component tasks, and the nature of the inputs and outputs, it is then necessary to organize the tasks into crew stations. For this purpose, the Checkout System's operating environment will be studied to estimate the frequency of the tasks and to formulate a first iteration of checkout procedures to estimate task times. These data will then be subjected to a time-line task analysis to assess loadings, to revise and further detail the first information flow concept, and to organize tasks into duty stations defined in terms of the tasks to be performed and the broad input and output characteristics.

With the duty station so defined, it will then be possible to select appropriate modes of display and control. Based upon the task, the type of information, the type of duty station, the speed and accuracy requirements of the response, and probably packaging constraints, it will be possible to differentiate between auditory and visual displays, pictorial and symbolic display formats, discrete and continuous control variables, and other alternative modes of display and control.

5.4.3 PERSONNEL AND TRAINING

To assure the maximum use of human engineering data and the compatibility of the equipment, manning structures, training programs, and technical data, it is planned that all of the data collected and developed for human engineering purposes will be maintained as a central human-factors data pool and that a simple storage and retrieval system will be effected to allow for ready access to these data. Clearly, the data developed on human functions, duty-station responsibilities, tasks, procedures, equipment specifications, and equipment designs represent the bulk of data needed to analyze personnel and training requirements, develop training programs, and prepare job-oriented technical data.

These job descriptions will be used as a basis for formulating the broad training program. The development of the training courses themselves will then flow quite naturally from the task data, which will provide a basis for selecting course content and for developing training materials and training aids.

The job descriptions and task data will also be used to determine technical-manual requirements and how the materials should be organized to enhance their usefulness. In some cases, as with the task procedures, the original task data can be incorporated directly into the manuals with little or no revision.

Because of the complexity of these systems and the uniqueness of many of the tasks to be performed, it is recommended that an explicit program of human-factors testing be undertaken as part of the engineering effort. This program will attempt to identify human errors in the performance of system missions and to provide diagnostic data that may be used to determine whether changes are necessary in equipment design, procedures, manning structures, or training programs. Since this test program will require some fairly sophisticated experimental designs and measurement methods, the planning of the program should be initiated as early as possible. Furthermore, it is adviseable that this program be integrated with the over-all engineering test program in order to minimize the need for special test time and special simulation.